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COMMUNITY WATER SYSTEMS IN THE UNITED STATES, THEIR PROTECTION AND THEIR IMPACT UPON HEALTH

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COMMUNITY WATER SYSTEMS IN THE UNITED STATES
(Their Protection and Their Impact Upon Health)

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1. A community water system, for the purposes of this discussion, is defined as the integrated delivery of a safe water, in ample quantity, into the individual household of every member of the community. It is implied that the provision of this amenity for potable, domestic, and industrial purposes is on an uninterrupted basis twenty-four hours a day, and 365 days a year. Full pressures on the water mains are likewise presupposed, under the sustained full-time management of a responsible local agency.

2. These detailed specifications are spelled out to distinguish real community systems from those intermittent water services, of sometimes safe quality, delivered at points remote from the user and at pressures often reduced to zero. Even these latter inadequate services are now only sparingly available to somewhat more than two-thirds of the population of the world. In retrospect, however, they represent a reasonable picture of the domestic water supply situation in the United States some 100 years ago. It is valuable, therefore, to retrace the history of community water development in this country, in order to determine the means by which this gap has been largely closed and to measure the impact which this development has had upon the public health and upon society in general. Not always were the people afforded this universal necessity and luxury for safeguarding life and cleanliness. Some of the lessons of the past, therefore, have important implications for accelerating the installation of water facilities throughout the globe.

The History of Community Water Expansion in the U.S.

3. The earliest public water supplies date from 1652 at Boston, about 1732 at Schaefferstown, Pa., and at Bethlehem, Pa., in 1761. At the close of 1800, only 17 water works were in operation. The number did not pass the hundred mark until 1850 and the thousand mark until 1885. By 1895, the figure had reached about 3000. At the close of 1924, it is estimated that over 9,000 water works were supplying about 10,000 communities.

4. The turn of the faucet was by then all that was necessary for thousands of people to secure either hot or cold water on any floor of a dwelling. The public water supply was already having its impact upon public health, the protection of life and property against fire, street sprinkling, sewer flushing and many industrial uses. These supplies were not only substituting safe for unsafe drinking water, but were also making water carriage sewerage systems possible, which in turn were abolishing the dangerous privy and cesspool.

5. The evolution of the systems under private sponsorship is of interest, particularly in view of the fact that, outside of the United States and much of the European areas, private ownership of community water systems is frowned upon and often prohibited. Yet in 1890, in the United States, of some 23,000,000 people supplied, about one-third was privately owned and operated. By 1925 over 85 percent of the people were provided by municipally-owned water works. Although this ratio had been materially altered by 1960, it is still true that approximately 20 percent of the people are served by privately owned systems. Private capital may have an honorable place in many countries in the development of new water systems, provided governmental policy and climate are favorable.

6. By 1900, about 30 million people had the advantages of a municipal water supply, with a use of some 3 billion gallons a day. In 1954, these figures had grown to over 100 million people, with a daily total use of some 16 billion gallons. The average use per person per day, for the country as a whole, was approximately 150 gallons.

7. Today, some 21,000 communities, serviced by some 18,000 systems, provide approximately 135,000,000 people with water facilities as earlier defined.

8. The continuing rapid urbanization and industrialization of the United States gives no basis for assuming that the provision of new water facilities is at an end or, in fact, may even be tapering off. On the contrary, all projections for the future show major increases in population and continued marches toward the urban areas. It is probable, therefore, that total demands by 1980 will reach at least 29 billion and by 2000 at least 43 billion gallons per day. Even the per capita daily uses will rise with the increase of the standard of living, and the wider use of water requiring household equipment, such as the automatic clothes washers.

The Cost of Facilities

9. Because of the long history of community water development in the United States no truly reliable estimate is available of the total investment in these facilities. It may be assumed, however, that it exceeds, for the complete systems, some 17,000,000,000 dollars. In the year 1958 alone, the capital expenditures reached almost 850,000,000 dollars.

10. Of much greater significance than these astronomical figures is the transcendent fact that unit costs or per capita annual costs are surprisingly and modestly low. This salient fact needs to be emphasized and re-emphasized in applying the lessons of United States experience to the solution of this important problem in developing countries. In these regions, the staggering capital investments required frighten the ministers of finance, of public health and of public works. Yet, the strengthening of borrowing power, the development of the principle of reimbursability, the fortifying of local responsibility in management and fiscal control, all change the emphasis in time from capital investment figures to annual costs per person. These latter amounts are not intimidating and are increasingly within the grasp of millions of people, when the realities of sound financing appear on the horizon.

11. The case history of the United States is again full of confirmation of these generalizations. For example, in 1954, the latest year for verifiable data, the average annual cost for water per person was $9.79, with a high in the arid Great Basin region of $13.67 and a low in the humid Chesapeake Bay region of only $7.97. Even with the great developments for community water projected for 1980 and 2000, involving billions of dollars of capital expenditure, the annual costs will remain $10 or less per person, on the average. These annual costs include operation, maintenance, interest and amortization.

12. Safe water delivered into the house is a remarkably cheap and plentiful commodity. It generally costs from 5 and 10 cents a ton. No limit should be placed on the amount furnished or the time at which it is available, provided it is not wasted or dissipated uselessly and the customer pays for it.

13. In general, these criteria have been the guiding ones in this country and increasingly they are being more fully met. Of equal importance, however, is the realization that this amenity has been universalized among urban dwellers almost entirely through local responsibility and local financing and repayment. So successful has this performance been for over 100 years, that water works bonds are rated among the highest priorities of safety in the open financial market. Defaults have been rare, interest rates often are less than 6% and frequently less than 4% annually, and periods of repayment in general extend to as much as 40 years.

14. These situations are evolutionary. They have not always been so. They reflect at least half a century of local responsibility and integrity, and a climate of political stability. Without them, public water systems will be slow in creation and non-generative in character. Central government subsidy, external largesse, in any form of gift rarely provide the above necessary ingredients. The major lesson of the United States experience is that the present 18,000 systems are predominantly the result of local financing, without any significant central government subsidy.

The Search for Pure Water

15. Man has pursued the quest for "pure" water for thousands of years. The criteria for purity have become during these centuries, more complex, more quantitative and increasingly more rigid. The search, of course, is never ending, because the world is not static, technology is ever on the move, populations and their consequent waste products eternally increase and because the consumer protection requires more and more complex controls.

16. The disease hazards of water, although empirically suspected in earlier years, were not the major motivations toward community systems. The chemical test long preceded the great progress of control in the biological era. To these have now been added the diagnostic indices for more exotic organic and inorganic substances in water, whose physiological effects are still but dimly understood. Accompanying all of these throughout the last century has been the ever-increasing demand by the consumer, often running ahead of the technologist, for esthetic perfections of superior palatability.

17. These advances in desire were naturally initiated by the forward march of water purification methods, closely followed by sewage treatment processes to guard and improve the surface and ground water sources of the community systems. The great progress in these installations, it must be again remembered, was made only over the last century.

18. Until 1870 no water filtration plants existed in the United States. In the 1870's the Poughkeepsie and Hudson, N. Y. slow sand filters were built, followed by those at Lawrence, Mass. in 1893. In the late 80's the earliest rapid sand units appeared. By 1897 over 100 of such installations had been built, and by 1925 about 587 rapid and 47 slow sand filters were already in use. They were delivering approximately 5 billion gallons per day.

19. At the turn of the 20th century, the great additional jump forward in water protection came about in the introduction, in 1908, of the use of chlorine for bacterial disinfection. Chlorination subsequently became the universal beneficial "vade mecum" of the sanitarian, both in water and in sewage treatment.

20. Installations for water treatment have proceeded at a high rate from 1925 to date. Simultaneously, however, sources of water have become increasingly polluted by familiar biological and chemical materials, reinforced by newer and less familiar types of industrial and other wastes, such as synthetic organic chemicals and radioactive materials. Many viruses and other disease-producing organisms add to the ever-growing control problems.

21. In spite of the delays due to economic depressions and wars, progress in pollution abatement has been great in the last 40 years. By 1957, over 7500 sewage treatment plants had been serving some 77 million people. An additional 22 million had sewerage at that time, although their 3000 communities were discharging raw sewage. The sewered population covered somewhat less than 100 million people in over 11,000 communities.

22. The tabulation which follows places these accomplishments in chronological perspective: (in millions)

Year	Urban Population	Sewered Population
1900	30	25
1920	54	50
1940	80	70
1960	126	105
1980	200 (estimated)	200 (estimated)

23. The sewage pollution abatement picture, however, still remains less than satisfactory, even though United States cities spent more money in 1961, for this purpose, than ever before. On January 1, 1962, some 5290 communities still had inadequate or no sewage treatment facilities. Their impact on drinking water quality, however, should not be exaggerated since water treatment processes have been singularly effective. In addition, less than 4% of the 5290 communities encompassed more than 5000 people apiece.

24. The expenditures in 1961 for sewage treatment were approximately 560 million dollars. Federal funds were represented in this amount to the extent of $1 of Federal money to every $5.50 of local municipality money. In prior years, by far the largest expenditure had its origin locally, unsupported by central government subsidy. For the future, the projected annual costs (operation, maintenance and amortization of investment) for collection and treatment will be $818 million for 1980 and $1200 million for 2000. The projected annual costs per person are again extremely modest, namely, less than $5.00 in 1980 or 2000.

The Impact Upon Public Health

25. Impure water has always been a carrier of disease. Contamination of water courses, surface or underground, has been the rule wherever there were people. The wastes of man have invariably been indiscriminately distributed in his environment. Since man has been the host of many diseases and many of these have spent part of their life cycle in the digestive tract, their causative organisms have found their way into human urinary and fecal discharges. The number and variety of these organisms have been myriad. They run the gamut from the ubiquitous typhoid fevers, amebic dysenteries, infectious hepatitis, schistosomiasis, and others too long to enumerate.

26. All of these diseases, not too long ago, plagued this country. All are in part water-borne. Today, many of these diseases are relegated to the classification of "tropical." This designation, however, is truly a misnomer, since these so-called "tropical" diseases at one time were universally distributed, in cold as well as hot climates. They have not, in fact, disappeared from the Western

World, but have been banished and controlled by environmental sanitary measures, such as water purification. When these measures are relaxed, the diseases recur.

27. In most developing countries, many of which are tropical, these sanitary restraints have not yet come into play on any large scale. Until they do, the enteric diseases will continue to take a major toll in disability and in lives.

28. The major lesson of the advent of community water for all the people in the United States is in the great accompanying reduction in the enteric diseases of water-borne character. Typhoid fever disappearance is a striking example of this accomplishment. This experience gives equal promise to other evolving countries. A brief review of its history in this country is pertinent, because it represents one of the most remarkable public health achievements since the turn of the twentieth century.

29. The typhoid fever deaths per 100,000 in 1900 were 35.8. By 1936 it had been brought down to 2.5, while today it is virtually zero. (Figure I) Minor recrudescences occur, but it is rare to see a typhoid case in an American hospital. Of equal significance is the fact that in the large cities, say over 100,000, the rates have consistently been notably lower than those for the Nation as a whole. Safety of water, coupled with pasteurized milk, have undoubtedly accounted for this prideful accomplishment. It can and should be matched in the next decades in the developing countries.

30. The role of water quality in the dissemination of enteric diseases, of course, has been recognized for more than 100 years. That pathogens causing the diarrheal diseases of children, typhoid fever, cholera, and shigellosis can survive in water and can cause illness to those who ingest the water is well known. Because of its comparative universality, typhoid fever morbidity and mortality data have been used as criteria of water sanitation, despite the fact that water is not the only mode of transmission of that disease. The increase in the number of municipal water supplies has paralleled closely the decline in typhoid deaths for over half a century. Undoubtedly, continuous disinfection of public water supplies with chlorine accelerated this decrease of water-borne typhoid fever. A very considerable decrease of water-borne typhoid occurred, however, even before the disinfection with chlorine became a common practice. This would seem to indicate that the installation of community water supplies, even though not all of the highest sanitary quality, may be expected to have an appreciable effect on typhoid fever death rates.

31. The annual reports of the Massachusetts State Board of Health prior to 1900 yield considerable evidence on the value of public water supplies in reducing typhoid fever, even before chlorination was adopted. Very early the Massachusetts Department of Health recognized the relationship between community water supplies and typhoid fever incidence. That department was the first state health department in the United States of America. It early assumed an active role in the promotion of community water supplies and investigation of the effect of such water supplies on the public health. The growth of water supplies and the corresponding typhoid fever death rates in the State is shown in Figure II.

32. In the case of typhoid fever and cholera, the principle involvement of the water supply is in connection with water which is ingested through the mouth. In the case of shigellosis and some of the infant diarrheas, there is increasing reason to believe that the availability of water supply in ample quantities may be equally or even more important than the bacteriological quality of the supply. In a well controlled study, Hollister et al have reported on the influence of water availability on shigella prevalence in children of farm labor families in the state of California, USA. Their studies confirm the impression of Watt who had postulated that water, even though it might be "below standard," could act as a diluent

and assist in the reduction of intestinal infection when used for personal hygiene purposes. Hollister and his colleagues compared the shigella positivity rates between camps which had cabins equipped with inside water faucets and camps which had a portion or all of the cabins with outside water faucets. Their data are shown in Figure III.

33. Wagner and Lanoix comment on a study carried on in Palmares, state of Pernambuco, Brazil, by the Servicio Especial de Saude Publica. This Brazilian study showed that there probably was a relation between the availability of water supplies and the deaths from diarrhea of young infants. The study also gave some indication that the health risk was about the same whether the treated water was carried from public fountains to private houses or whether water was taken from open unprotected "wells."

34. The record of the impact of water supply upon disease in the United States gives no basis for assuming that control and eternal vigilance may be dispensed with, once water systems are provided. We have a long history of recurring water-borne disease when such vigilance has been relaxed. Unfortunately, the disappearing enteric diseases do lead to the impression that water-borne epidemics are no longer to be feared as they were in the past. Those who hold this viewpoint must take heed of the toll exacted by these diseases since 1920, even while the total picture has been amazingly good.

35. Perhaps one of the stimulating forces in the rapid development of purification lay in the attitude of the courts in the award of damages against private and public corporations found responsible for illness resulting from pollution of water supplies. In several instances the damages were high, as in the case of Olean, N. Y., where the city had to issue bonds to the extent of $350,000 to pay the costs incurred in a water-borne typhoid fever epidemic of 1929. An incomplete listing now accounts for such payments in somewhat over two dozen instances.

Global Implications

36. Recently, Dr. Abraham Horwitz, the Director of the Pan American Health Organization, speaking from his experience in his native Chile and from the results of his programs in North America, Central America, and South America, made the following statement:

> "If a single program were chosen which would have the maximum health benefits, which would rapidly stimulate social and economic development, and which would materially improve the standard of living of people, that program would be water supply with provision for running into or adjacent to the house."

37. Despite the deficiencies in the reporting of enteric diseases in many developing countries, it is clear in all of them that the mortality from typhoid fever, gastritis, enteritis, etc., is excessively high. It ranges in the figures prevailing in North America in the last period of the 19th century. As a matter of fact, for all age groups and particularly for infants and children 1-4 years of age, the diarrheal diseases rank either first or in the first five of the principal causes of disability and death.

38. As Dr. Horwitz points out, and as is generally accepted by most health officials, a major reduction in these diseases is possible, quite independent of etiologic and sociologic differences in countries or regions, by the provision of potable water in sufficient quantities to keep clean and conveniently accessible to people. In such programming, safe water for the thirsty is not the sole objective and greater quantities of water must be provided for all the other amenities of cleanliness and urban living.

39. The situations in two regions of the world may illustrate both the public health need and the deficiencies in community water service. In the Central and South Americas, the deaths from the enteric diseases are still higher, in some countries, than 200 per 100,000, and figures in excess of 100 per 100,000 are common. Of the 16 countries of Latin America, in the age group 1 to 4 years, diarrheal diseases were the leading cause of death in 11 and among the first five principal causes in the remaining five. These facts are graphically demonstrated in Figure IV.

40. Using water service as hitherto defined, the availability of water in the Americas is sadly deficient. Out of 75 million people in cities of more than 2000 population, 29 million are without such service. Almost 50 percent of the people in cities of 10,000 to 50,000 are in the same deficient category. More than 70 percent are without service in cities of 2,000 to 10,000. In rural areas, matters are even worse. Of these 107 million people, far more than 70 percent are without water service.

41. The leaders of these countries are of course well aware of these deficiencies and of the snail's pace in their correction. This understanding is well reflected in the Charter of Punta del Este which calls for the provision of adequate water supply, sewerage and excreta disposal, in the next ten years, for at least 70 percent of the urban and 50 percent of the rural population. To accomplish this sound purpose will require strong support for the prompt and continuing adoption of the fiscal, engineering and managerial principles which have resulted in the great progress in the United States.

42. In another part of the globe, India, similar disease and water deficiencies confront the policy maker. The issues are the same as previously discussed. They are well recognized. Impatience with the slow pace of community water development over the last 20 years drives this country toward the realization that a new look, at an old problem, is demanded.

43. Such a new look in India was completed in 1961 by a Special Committee created by the Ministry of Health, Government of India, by an order dated April 28, 1960. The inquiry resulted in conclusions and recommendations issued in 1962 by the Committee on National Water Supply and Sanitation. Its findings warrant brief restatement here in abbreviated form:

(a) For the urban population of 78,000,000, about 34 percent were judged as adequately served with water, 26 percent inadequately and 40 percent not served.

(b) For the same urban population, adequate sewerage service was available for 21 percent and no service for 68 percent.

(c) In the rural areas, defined by the Committee as encompassing some 300,000,000 people, progress on individual well installations aggregating over 500,000 in number is significant, but unsatisfactorily slow.

44. The closing of these sanitary gaps in India, it is recognized officially, will require "a new path to be cut if the program is to succeed and move on its own momentum. Local bodies should be encouraged to promote urban water supply and sewerage schemes as a self-paying industry, just as electricity undertakings are promoted and operated. The method of financing of such schemes should be patterned after the procedure and practice which have succeeded and established themselves in the more advanced countries, with such modifications as are dictated by conditions in this country."

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CONFERENCIA DE LAS NACIONES UNIDAS
SOBRE LA APLICACION DE LA CIENCIA Y LA TECNOLOGIA
EN BENEFICIO DE LAS REGIONES MENOS DESARROLLADAS

Punto del programa : A.1.1 Chile

LA AEROFOTOGRAFIA, FOTOGRAMETRIA Y FOTOINTERPRETACION EN LA OBTENCION DE INFORMACION BASICA PARA EL DESARROLLO ECONOMICO

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Las monografías presentadas en la Conferencia de las Naciones Unidas sobre la Aplicación de la Ciencia y la Tecnología en Beneficio de las Regiones Menos Desarrolladas constituyen documentos de trabajo de dicha Conferencia. Se publican tal como han sido presentadas por los colaboradores y los puntos de vista expresados en ellas corresponden a los colaboradores. (Veanse notas al dorso.)

NOTAS

1. Las monografías seleccionadas para las Sesiones Generales serán distribuidas en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

2. Las monografías seleccionadas para las Sesiones Especiales serán distribuidas en la Conferencia únicamente en uno de los idiomas oficiales antes indicados.

3. Los resúmenes de las monografías presentadas por los colaboradores serán distribuidos en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

4. No se procederá a la distribución general de las monografías y resúmenes con antelación a la Conferencia. Unicamente serán publicadas en cantidades limitadas con antelación a la Conferencia para uso exclusivo de las delegaciones de los gobiernos participantes y de otros participantes autorizados. La publicación con posterioridad a la Conferencia y la distribución general de las actas y debates de la Conferencia seguirán las prácticas de las Naciones Unidas establecidas por la Junta de Publicaciones de las Naciones Unidas.

LA AEROFOTOGRAFIA, FOTOGRAMETRIA Y FOTOINTERPRETACION EN LA OBTENCION DE INFORMACION BASICA PARA EL DESARROLLO ECONOMICO

por

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1.- INTRODUCCION

La preparación de proyectos específicos que implementen los programas o planes de Desarrollo Económico ha hecho evidente que es indispensable disponer de antecedentes que permitan formularios basados en el conocimiento cierto de los elementos sobre los cuales se va a actuar.

Entre estos antecedentes se encuentran aquellos relacionados con el terreno mismo y sus recursos naturales, además de los antecedentes económicos y sociales que condicionan las posibilidades del Desarrollo.

En las Zonas Central y Sur de Chile, comprendidas entre los paralelos 32° y 43°30', que abarcan las provincias más pobladas del país con un 89% del total, se encuentra la mayor parte de la actividad agrícola.

La sub-división predial, los cultivos, la red de caminos y obras de regadío, tienen en ellas su mayor desarrollo, aunque esto no significa que se disponga de toda la información adecuada para una completa planificación del Desarrollo Económico y de las modificaciones necesarias en la tenencia de la tierra, impuestos territoriales, determinación de prioridades de obras públicas, etc.

La obtención de estas informaciones es la finalidad fundamental de un proyecto que se realiza en las Zonas señaladas con la participación del Gobierno de Chile y la Organización de Estados Americanos (O.E.A.).

2.- EL PROYECTO AEROFOTOGRAMETRICO O.E.A. - CHILE

a.- Este proyecto consiste en un estudio de recursos naturales y realidades existentes en areas rurales utilizando como elemento básico la fotografía aerea complementada con visitas al terreno.

b.- Se realiza por una parte con el personal técnico (aprox. 160) de seis ministerios del Gobierno de Chile, y por otra, con el personal especializado (aprox. 45) de un Grupo Ejecutivo formado por cuatro compañías dedicadas a este tipo de estudios y que fué contratado especialmente por la Organización de Estados Americanos a pedido del país.

c.- Las informaciones obtenidas quedarán indicadas sobre mosaicos a escalas 1 : 50.000 y 1 : 20.000 que serán utilizadas en: el reavalúo de los predios agrícolas del país necesario para la Reforma del Sistema Tributario; en la realización de los planes de Colonización y Reforma Agraria; en el establecimiento de sistemas de Créditos supervisados a la Agricultura; en la Planificación del mejor aprovechamiento de los terrenos de acuerdo a su Capacidad de Uso; en la preparación de censos agropecuarios y obtención de datos estadísticos; en el conocimiento de las formaciones geológicas, recursos mineros y petrolíferos; en la determinación de prioridades y ejecución de obras públicas que influyen directamente en el desarrollo económico como caminos, obras de regadío, planes urbanísticos; en la preparación de una carta topográfica nacional a escala 1 : 50.000 con curvas de nivel; en la determinación exacta de los límites administrativos que serán utilizados por el Sistema de Gobierno Interior del país.

d.- El Proyecto se realiza sobre 120.000 Kms^2 del territorio nacional comprendidos entre las provincias de Aconcagua (paralelo 32°) y Chiloé (paralelo 43°30').

Incluye además 8.000 Kms^2 de seis Valles transversales ubicados entre las provincias de Atacama y Aconcagua.

En las provincias australes de Aysén y Magallanes se obtendrán fotografías aéreas a escala 1 : 50.000 sobre 110.000 Kms^2 en las areas de mayores posibilidades de desarrollo.

e.- Las distintas etapas que se indican a continuación constituyen la forma en que se utiliza la fotografía aérea y los medios establecidos para recopilar las informaciones del terreno. Se indica en cada una de ellas el avance que se ha obtenido durante el tiempo que se ha trabajado.

Fotografías Aéreas - Durante los meses de Enero - Febrero y Noviembre - Diciembre de 1961 se obtuvieron fotografías aéreas a las escalas que se indican:

1 : 50.000 sobre 150.000 Kms^2 de la Zona comprendida entre Concepción (paralelo 37°) y Chiloé (paralelo 43°30') de todo el territorio nacional.
1 : 20.000 sobre 70.000 Kms^2 del Valle Central comprendido entre Aconcagua (paralelo 32°30') y Puerto Montt (paralelo 43°30').
1 : 10.000 sobre 900 Kms. de areas urbanas y sub-urbanas sobre 8 ciudades de la Zona Sur, afectada por los sismos de 1960.
1 : 30.000 sobre 8.000 Kms^2 de los valles transversales al norte de Aconcagua.

Control Topográfico - Durante los meses de Marzo a Septiembre de 1961 se estableció o revisó dos tipos de control topográfico de acuerdo a su utilización posterior: Control en las Areas urbanas y sub-urbanas para la restitución de planos topográficos sobre 300 Kms^2 en las ocho ciudades de la Zona Sur, y Control de Triangulaciones o poligonales para producción del control radial indispensable en la elaboración de mosaicos de fotografías aéreas a una escala constante. Se efectuó este último trabajo sobre 120.000 Kms^2 revisando 150 puntos de triangulación y estableciendo 70 nuevos puntos por poligonales. En esta etapa se contó con la colaboración del Instituto Geográfico Militar y la Fuerza Aérea de Chile ocupando los más modernos sistemas electrónicos de medición de distancias y los helicópteros para la movilización en el terreno.

Producción de Planos y Mosaicos - Para las 8 ciudades de la Zona Sur se restituyeron planos topográficos a escala 1 : 2.000 con curvas de nivel cada metro. Esta labor se realizó por personal y con equipos extranjeros.

Con el fin de obtener rapidamente mapas donde vaciar las informaciones se prepararon mosaicos controlados de fotografías aéreas a escalas de 1 : 20.000 y 1 : 50.000 de 120.000 Kms^2 comprendidos entre los paralelos 32°30' y 42°; y entre el pié de la Cordillera de Los Andes y el mar. Esta área quedó cubierta por 470 mosaicos a 1 : 20.000 y por 85 mosaicos a 1 : 50.000 que se completaron entre los meses de Septiembre de 1961 y Febrero de 1962 por el personal y equipo extranjeros.

Identificación de Predios Agrícolas - En la Zona que cubre el proyecto se estima que existen 200.000 predios rurales que en las avaluaciones anteriores se habían identificado en croquis a mano alzada ya que el único material cartográfico que cubre todo el territorio que existía era la carta preliminar a escala 1 : 250.000 preparada por el Inst. Geográfico Militar. En ella 1 cm^2 representa 625 Hás. del terreno, y los predios cuyo avalúo es inferior a E° 5.000 en dicha area se estima que alcanzan a 185.000.

Con la participación de aprox. 60 funcionarios dotados de vehículos se han logrado identificar en el terreno sobre las fotografías cerca de 60.000 predios que representan un 55% del area total. Los deslindes se han marcados en las fotografías y después de vaciar esta información a los mosaicos se han medido las superficies de 10.000 predios con un grupo de 15 personas contratadas especialmente. Toda la labor desarrollada en el terreno que se indicó anteriormente se ha desarrollado en un período de un año entre los meses de agosto de 1961 y 1962 especialmente por personal de la Dirección general de Impuestos Internos.

Uso actual de los Terrenos - Este trabajo se efectúa por fotointerpretación principalmente, clasificando los terrenos de acuerdo a una clave con nueve grupos cuyos sub-grupos se han adaptado a los cultivos del país. Aproximadamente 15 Ingenieros Agrónomos del Ministerio de Agricultura fueron entrenados especialmente por 10 especialistas extranjeros los que en conjunto han completado más de 375 mosaicos con esta clasificación en 12 meses de trabajos, esta cantidad representa un 80% del area total alcanzando a 80.000 Kms^2 ó 8.000.000 de Hás.

Capacidad de Uso de los Suelos - La determinación de la capacidad de uso de los suelos agrícolas se está realizando con el estudio de los factores de GEOMORFOLOGIA Y GEOLOGIA; SUELOS Y FACTORES LIMITANTES A LOS CULTIVOS; HIDROGRAFIA y CRECIMIENTO DE PLANTACIONES FORESTALES.

La interpretación de geomorfología y geología, proporciona antecedentes sobre las formas de la tierra, pendientes medias, y origen de los materiales que forman el suelo agrícola.

A su vez el estudio de los suelos señala las caracteríesticas de estructura, textura y factores limitantes al cultivo de los suelos.

Los estudios de Hidrografía permiten trazar sobre los mosaicos los sistemas de canales de regadío, y además se está recolectando todos los antecedentes disponibles sobre derechos de aguas y caudales existentes en los meses de riego.

Con los estudios de crecimiento en las plantaciones forestales relacionados con los suelos donde se encuentran se ha permitido conocer que los pinos insignes tienen el doble de crecimiento en un mismo período de tiempo y lugar geográfico si están plantados en terrenos de primera clase que si ellos se encuentran en terrenos de cuarta clase.

Todos estos estudios permiten clasificar y delimitar sobre los mosaicos a escala 1 : 20.000 los terrenos agrícolas de acuerdo a una clasificación internacional que tiene ocho grupos de capacidades de uso.

Hasta el momento con la participación de 15 agrónomos chilenos y 10 especialistas extranjeros se ha podido completar en un lapso de ocho meses durante 1962, un 25% de los 470 mosaicos que cubren el área total. Esto representa una superficie aproximada de 3.000.000 de Hás. equivalente a 30.000 Kms^2.

Aeromagnetismo y Fotogeología - Para fines específicos de prospección petrolífera y minera se han completado estudios de aeromagnetismo y fotogeología sobre un área de 70.000 Kms^2 comprendida entre los paralelos 35°30' y 43°30'. La coincidencia de anomalías en el campo magnético terrestre y de ciertas condiciones de formaciones geológicas y drenaje natural han señalado tres lugares como los más favorables para efectuar perforaciones exploratorias para recursos petrolíferos. Este trabajo que se encuentra casi terminado, se ha completado en un período de un año participando en él principalmente personal especializado extranjero.

f.- Origen del Proyecto y Financiamiento - Todos los trabajos se iniciaron en Enero de 1961 con la obtención de fotografías aéreas de las zonas afectadas por los sismos de Mayo de 1960 y financiadas con un Fondo Especial de ayuda a Chile de US$ 500.000 creado por la O.E.A. con un aporte extraordinario de los países miembros.

Al conocerse en Marzo de 1961 la utilidad de las fotografías aéreas y sus posibilidades, la Empresa Nacional del Petróleo (ENAP) decidió financiar aquellos estudios que, basados sobre fotografía aérea y sus técnicas derivadas, tuvieran relación con la prospección de petróleo, aportando un monto de US$ 350.000.

En Mayo de 1961 el Gobierno de Chile solicitó a la O.E.A. la extensión del proyecto a toda la zona agrícola que se ha indicado, señalando especificamente el interés en las informaciones de Identificación de Predios, Uso Actual y Capacidad de Uso de los Terrenos. Para esto financió las dos primeras de estas etapas aportando a la O.E.A. US$ 600.000 y E° 70.000 durante 1961.

Para la extensión de la fotografía aérea a las otras zonas y la determinación de la Capacidad de Uso de los Terrenos, se ha obtenido un préstamo del Banco Interamericano por US$ 200.000 y US$ 1.900.000 respectivamente.

Por otra parte el Gobierno de Chile ha financiado para gastos locales de movilización , viáticos, etc., a través del presupuesto de la nación de 1961 y 1962 la suma de US$ 870.000 equivalente a E° 920.000.

Se estima el aporte indirecto por servicios de profesionales, oficinas e instalaciones proporcionados por Instituciones Públicas en E° 1.008.000 equivalente a US$ 960.000.

g.- La totalidad de las informaciones deberán entregarse en Diciembre de 1963, pero debido a la enorme utilidad que ellas prestan en los diversos campos que se han indicado en el párrafo c.-, desde ya se están utilizando a medida que se van completando.

Además, entre los particulares y las empresas relacionadas con recursos naturales han solicitado tal cantidad de material de fotografías aéreas y mosaicos que ha sido necesario instalar una sección especial para su atención permanente.

Adjunto a la presente descripción general se incluyen gráficos explicativos de las diferentes operaciones que cumple el Proyecto y las zonas que cubre.

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United States of America

THE IMPORTANCE OF GEODETIC CONTROL AND THE ADVANTAGES OF ITS NEW TECHNIQUES

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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THE IMPORTANCE OF GEODETIC CONTROL AND THE ADVANTAGES OF ITS NEW TECHNIQUES

by

No. 683
A.1

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1. The existing vast geodetic networks of the world took many scores of years to establish. Modern techniques were not available, transportation was difficult in the early periods, instrumental equipment was bulky, and procedures were very slow, to say the least. With modern air transportation, lightweight equipment, and new techniques, geodetic triangulation or traverse of almost any desired accuracy now can be accomplished in a relatively short time.

Purposes of Geodetic Control

2. The primary function of geodetic control is, of course, to furnish the basis for mapping. A small island or an area of several thousand square miles could be mapped without geodetic considerations, but areas of continental extent should be mapped on a geodetic base. Since practically all countries are parts of continents, it follows that, if the mapping is to be at all integrated, the first consideration is that of geodetic control. Unlike mapping, which must be revised every generation or oftener because of cultural changes and need for larger scales, accurately executed geodetic control can serve its purpose a century or more after its original establishment.

3. But mapping is not the sole function of geodesy. The construction of cities and towns, of roads and highways, of railroads and airports, and the development of water resources, including the erection of huge dams for irrigation and hydro-electric power, all require large-scale surveys. It is certainly good planning to place all these engineering activities on a firm, common geodetic base.

4. There are many other uses to which a good geodetic base can be put. The delineation of national and provincial boundaries, and the survey of public and private property lines, are good examples. Surveys for pipe and transmission lines, when coordinated by geodetic control, can be accomplished in a more orderly and accurate fashion then otherwise. The exacting demands of bridge and tunnel construction can be met only by geodetic survey procedures. And when such surveys of a local nature are incorporated into the national geodetic network, they will be coordinated with the more extensive geodetic surveys essential to the construction of transcontinental railroads and highways.

Horizontal Datums

5. We have not passed from the spheroidal era to the geoidal era.[1] In fact, this transition occurred many years ago. Whereas the spheroid is a smooth mathematical surface (ellipsoid of revolution), the geoid is the actual surface of the earth as defined by the level of the sea and its extension under the continents, were it allowed to flow freely with the continents in place. Although it closely approximates a spheroid, the geoid has its humps and hollows, a description more picturesque than accurate. But this wrinkled surface, while it deviates by no more than a few tens of meters from the spheroid, causes trouble in establishing a geodetic datum.

6. It is possible through refined observations on the stars to determine astronomic latitudes and longitudes within possibly five meters on the earth's surface.

Unfortunately, such observations are necessarily referred to the direction of gravity which, in turn, is always perpendicular to the geoid, not the spheroid on which triangulation is computed. Thus, the vertical is said to be deflected and a deflection of one minute of arc, which is possible, could result in error in the position of an observation station by as much as one and one-half kilometers.

7. To establish a geodetic datum more or less free from the effects of the gravity vertical, the following procedure, in substance, has been followed by many countries. The latitude and longitude of some initial point are assumed (usually determined by astronomical methods) and the triangulation is observed radiating from this initial point. As the survey progresses, the latitudes and longitudes are calculated on the surface of the adopted spheroid. At the same time, the astronomic positions of many of these triangulation stations are determined. The differences in the latitudes, and the differences in longitudes, astronomic minus geodetic (A-G), are computed for each such station. A study of these differences, particularly in regard to their distribution, will indicate the correction which must be applied to the assumed position of the initial point to reduce the algebraic sum of the quantities (A-G) to a minimum. If there are enough of these combined geodetic and astronomic positions distributed throughout the network, this method of minimizing the (A-G) quantities should produce a satisfactory datum.

8. In the case of a small developing nation, four or five sites may be selected for astronomic observations. These should be spaced from one hundred to three hundred miles apart to form a more or less symmetrical figure. All possible lines connecting these points should then be measured by the airborne Shoran technique described later. Data are then available for an adjustment process by which the algebraic sum of the (A-G) values is minimized. The resulting datum is, in effect, an average of the individual astronomic datums and, as such, is much better than any one of them.

Horizontal Control Operations

9. Triangulation has been the basis for primary horizontal geodetic control for nearly three centuries. A triangulation system consists of a network of triangles whose vertices are marked points on the ground. All angles are accurately measured, and the lengths of the sides are computed successively through the chains of triangles, starting with a side which is actually measured on the ground. These measured sides or base lines are inserted at intervals to maintain accurate scale. Also, the bearing, or azimuth, of an occasional triangle side is observed astronomically to maintain accurate orientation.

10. The lengths of the lines vary considerably depending on the terrain and on the desired density of control points. During the early work in the United States triangle sides were seldom less than five miles in flat terrain and ranged up to 150 miles in mountainous country. Chains of quadrilaterals, called arcs, were spaced from 100 miles to 400 miles and were adjusted simultaneously to form the basis of the 1927 North American Datum. Later on, more closely spaced arcs of triangulation were added to break down this skeleton framework, and at the present time the spaces between arcs are being filled in solidly to form the area type of triangulation. For areas of limited extent, the area type of coverage should be given preference over the arc type.

11. While accuracy in angle measurement has not increased much in the past century and a half, there has been a tremendous improvement in instrumental equipment. The best theodolites in the early days of geodetic operations had circles as large as 36 inches in diameter, whereas the circles of modern first-order theodolites are less than 6 inches. Also, the modern instruments are much more precise. Astronomic equipment also has been reduced in size and increased in efficiency. But the most spectacular innovation deals with the measurement of distances.

Electronic Surveying

12. As a result of blind bombing techniques and rapid advance in electronics during World War II, the geodesist found that he had a new yardstick to work with--the speed of

electro-magnetic waves. He had the means, through electronic distance measurement, to increase the accuracy of his work, reduce the costs, and even accomplish surveys theretofore impossible.[2]

13. Airborne Shoran[3], was the first of these methods to be employed in geodesy. The procedure involves using Shoran equipment in an airplane to continually record the distances to each of two ground stations as the airplane flies a course perpendicular to a line connecting the stations. The distance between the stations is then determined from the minimum air-distant sum recorded, and the length is reduced to sea level. Shoran employs radio waves in the high frequency band, and length determinations have an accuracy of the order of a few meters. There are problems in correcting such observations for the speed of radio waves in actual atmospheric conditions, but the method makes possible surveys over wide stretches of water or in regions highly inaccessible and not adapted to the classical methods. Major Shoran projects, later called Hiran because of higher instrumental accuracy, have provided networks over the Caribbean area; northern Canada; the North Atlantic, connecting the European and American continents; and over certain Pacific island areas. This Hiran approach, though costly, is one way to rapidly arrive at a geodetic datum for areas far removed from well established datums.

Satellite Triangulation

14. With the advent of the artificial earth satellite, an entirely new approach to geodetic problems became available.[4] A continuing problem of interest on a world basis to geodesists is the interconnection of the continental and island geodetic datums and ultimately the establishment of a valid world geodetic datum. While progress has been made in intercontinental geodetic ties, the launching of artificial satellites offered the first truly universal technique of accomplishing these ties on a world wide basis. The necessary triangulation to provide these ties can now be accomplished by means of simultaneous observations on artificial earth satellites, the passive type, as ECHO I, and the rebound type, A-13, to be launched in 1963. These satellites are large, in high orbits, well illuminated by the sun and have long lives, allowing time for observations on a protracted time scale so necessary for optical photography, since about 70 per cent of the earth is blanketed by clouds at any given epoch of time. The technique will also have direct application in the dynamic studies of the earth's asymmetric gravity field, and in improving our knowledge of the earth's size and shape.

15. The U. S. Coast and Geodetic Survey has initiated a program of satellite triangulation. From a single camera site a satellite is photographed against the stars at a known time, and the position of the satellite image relative to the star images on the photographic plate is measured. The right ascension and declination of each star, obtained from star tables in the vicinity of the satellite image (about 20 stars), together with the plate measurements, are used in an adjustment procedure, or plate reduction, to obtain a right ascension and declination of the satellite. That is, a direction is obtained in space from the station, not involving the gravity vector at the camera site. Each camera plate has a succession of time-correlated images on it, and thus a plate reduction for each image gives a series of time-correlated right ascensions and declinations. These may be converted into corresponding time-correlated azimuths and elevations at that camera station. If a camera is used simultaneously from each of the ends of a known earth base line, then for each simultaneous satellite image on their plates there is a triangle formed by the satellite image and the two stations. The time-correlated azimuths and elevations from each camera plate are used along with the known length of the base line to compute the sides and angles of each space triangle. If a third camera of unknown ground position also photographs the satellite at the same time, then its time-correlated azimuths and elevations (matched in time with those of the other two) allow determination of its position with respect to the other two. The additional angular data will allow computation from the given base line through several sets of space triangles (successive tetrahedrons) to the third camera site. From this beginning the process can be continued and oceans

can be bridged, the satellite being used as a high flare in the sky to connect geodetic datums.[6]

16. To scale the satellite triangulation, base lines hundreds of miles long will be established accurate to 1 part per million. These base lines, in the form of highly precise traverses, will cross the entire continental United States in both directions. The instrument to be used is the Geodimeter, the characteristics of which are covered later. A simultaneous adjustment of this network will provide a geodetic base of five or ten times the present accuracy. Present plans call for establishing this very accurate geodetic network and then extending it by satellite triangulation to Puerto Rico, the Bahama Islands, Bermuda, and Panama with possible connections to the northeast coast of South America and the western coast of Africa. Further expansion is contemplated to the northwest to include Alaska and the Aleutian Islands. Extension can then be made to the Pacific Islands, such as Hawaii, the Tokyo Datum, Southeastern Asia, Southwest Pacific and Australia. With international cooperation an accelerated schedule could be devised, and the means provided for extending the net over South America, Europe, Asia, and Africa.

17. The camera system adopted by the Coast and Geodetic Survey for satellite triangulation is an adaptation of the Wild BC-4 with an especially designed lens system for photographing satellites, and with associated electronic timing and synchronization systems. A specially designed "chopping" shutter allows interruption of the satellite trail for timing purposes. Present plans include use of atomic clocks at station sites to eliminate timing errors in the coordination of the observations from the several station sites.

18. Five systems of four cameras each for operation in the several continental and island areas of the world would be adequate to assure success in the program. If, in addition, the many observatories throughout the world could participate, the objective of a rigid accurate worldwide reference network of geodetic stations for the precise observation of satellite orbits, study of the earth's figure, etc., would probably be realized much sooner.

19. The high accuracy Geodimeter traverse program is under way in the United States. The present plan is to cross the country east and west with about four, and north and south with about seven, of such traverses. A special design for the traverse surveys is being employed. At every other traverse station a second station monument is placed close to the main station (25 to 50 meters). In this way, long sliver quadrilaterals are formed. All angles and sides are measured. The short 25- to 50-meter length is taped. In this way rigid checks are obtained for both length and angle observations as the traverse survey progresses. Laplace azimuths are observed at every other traverse site, usually at the single monumented station. Since the Geodimeter-measured legs of the traverse are roughly eight to ten miles long, there will be a Laplace azimuth and a deflection of the vertical determined every 15 or 20 miles along the traverse. Thus, as a by-product, valuable information will be available for the study of the spheroid-geoid relationship.

Modern Equipment

20. The Geodimeter is perhaps the most revolutionary geodetic instrument in the long history of geodesy. It operates on a modulated light source, and since the speed of light has now been determined with an accuracy of better than one part per million, the Geodimeter can be and has been used to measure the lengths of lines to an accuracy of one part per million. It tremendously reduces the time and costs of measuring a base line. This means that the less developed countries have a tool of high geodetic precision in getting surveys under way at the outset. The tedious clearing, staking, and taping of a base line are completely obviated. The United States plans to use the Geodimeter to upgrade the scale of its geodetic networks, in addition to using it for the proposed satellite triangulation.

21. Unlike the Geodimeter, the Tellurometer operates on radio microwaves in the 10-cm. range. A similar and more recently developed device, the Electrotape, operating in the 3-cm. range, gives promise of high accuracy over a wide distance range. This

type of electronic distance-measuring equipment has proven to be another valuable tool for geodesy. It is not a competitor of the Geodimeter but is complimentary to it. The Tellurometer has two distinct advantages over the Geodimeter. It can be used in the daytime and even in foggy or hazy weather, and it is much lighter in weight. The system consists of two instruments: the Master and the Remote which, in recent years, have been made interchangeable. Whereas the Geodimeter has a basic uncertainty of one or two cms., the Tellurometer has such an uncertainty of about six or eight cms. Moreover, the radio wave type of instrument can have large errors due to reflected waves which are not present in the light wave type of equipment.

22. But the Tellurometer and Electrotape, when properly used, can yield second-order accuracy provided the lines to be measured are at least two or three miles; and they have been used to scale first-order triangulation where the lines were ten or more miles in length. When used in this fashion at least two lines of a triangle are measured to guard against too large an error.

23. The Tellurometer has been employed in the United States in supplying control for the interstate highway system. It is used both for measuring the legs of traverse surveys and in combined traverse and triangulation surveys. In adjusting the work to high-order triangulation, the average correction to a Tellurometer observation has been about 1:35,000. Tellurometer or Electrotape traverse would be an excellent method for filling in the gaps between first-order geodetic control with second-order traverses in new areas.

24. These items of new equipment, by which lengths of survey lines can be quickly and accurately measured, provide a great flexibility for the emerging nations in planning the extension of geodetic control. Triangulation, electronic distance-measured traverse, trilateration, or various combinations of these can be adapted to best suit climate, terrain, and any other conditions that may prevail.

Vertical Datums and Control

25. The establishment of a vertical control datum is completely separate from that of a horizontal datum.[7] Most of the developed nations of the world depend on the mean level of the sea for elevation datum.

26. Ideally, mean sea level is defined as the equipotential surface which the oceans of the earth would assume if not disturbed by the tides and meteorological effects. The geodesist in starting his precise leveling from a point on such an ideal surface would have no difficulty in closing his circuits on other such points along the coast. Elevations so derived would refer to a universal and unique mean sea level, an equipotential surface with zero potential. But, as usual, the ideal situation does not exist. The effects of the winds, ocean currents, atmospheric pressures, configuration of the coastline, and other disturbing elements, preclude an exact determination of this ideal surface by averaging the varying height of the sea. And this is so, even though tidal observations are taken over the full tidal cycle of 19 years. It becomes necessary, therefore, to establish tide gages and make observations at a number of stations along the coast.

27. The selection of locations for tide gages for the control of a level net depends on many factors, such as the coast line of the country under consideration, free communication for the tide, sufficient depth of water at all stages of the tide, freedom from runoff effects, and access to the interior to establish ties to the control nets. What is desired is a location at which zero potential can be determined. Mean sea level, as determined by averaging the hourly heights of the tide over a long period of time, can approximate this zero potential but cannot exactly be equal to it, since it is extremely difficult to remove all of the disturbing elements.

28. The density of tide station distribution is one which should not arbitrarily be placed on a distance basis. If along a coast the tidal regime is about the same for a long distance, control tide stations spaced 100 miles apart can be considered as adequate and desirable distribution. However, there are a number of places where the type of tide varies considerably at two localities much less than 100 miles apart. In these cases, a study should be made of the area and a sufficient number of control tide stations

established so that all of the various tidal conditions will be adequately covered.

29. In using mean sea level as zero in the establishment of a vertical control datum it is important that the observations be simultaneous. Along the coasts of the United States mean sea level is rising in varying amounts up to 0.021 foot per year. Along the Atlantic coast the rate is about 0.011 foot per year, while along the Gulf coast it is about 0.021 foot per year and on the Pacific coast about 0.005 foot per year. In view of the changes in mean sea level, it is readily seen that if data for different epochs were used there would be differing results.

30. The International Union of Geodesy and Geophysics has recommended that each country consider the computation of geopotential heights for each bench mark as well as orthometric heights. The geopotential heights would be based on measured values of gravity determined along the route of the leveling. This might make it desirable to use a single zero potential determination as a basis, especially if the level net is of high quality. Some countries have used mean sea level as determined at only one location as a basis for their elevations, as in the case of Great Britain.

31. The classical method of running levels to determine elevations has undergone little change. In order to secure high accuracy, the lines of sight seldom exceed 100 meters and on steep grades these are considerably less. In regions where there are no railroads or very few roads of any kind, the progress is apt to be slow due to transportation difficulties. The method, however, does yield high accuracy in comparison with determining elevations by observing vertical angles over a triangulation net. The classical method must be used as the basis of vertical control in any region where accuracy greater than that required for topographic mapping is desired. A new area should be covered with a network of leveling lines of first-order accuracy spaced from 50 to 100 miles in both directions. First-order leveling is double run, once in each direction. Second-order leveling, which may be used to break down the first-order loops, is generally run in one direction only.

Plane Coordinates and Projections

32. Over areas of large extent, precise control surveys must be computed and adjusted on the curved surface of the earth, else unmanageable confusion will result. The coordinates resulting from such computations are necessarily expressed in terms of latitude and longitude. After this has been accomplished, thought must be given to means of both mapping and surveying on a plane surface. For most types of engineering and cadastral surveys, it is almost mandatory that a system of plane coordinates, based uniquely on the adopted geodetic datum, be made available.

33. Projections may be said generally to serve two primary purposes--cartographic and geodetic or, in other terms, mapping and surveying. In some nations more than one type of projection, each of varying extent, is employed, such as in the United States. For cartographic purposes, the United States uses the Lambert conformal conic projection of zones some 25° in width for its sectional aeronautical charts and the same projection for zones 4° wide for the world aeronautical chart series. The Mercator projection is the basis for nautical charting in the United States. The universal transverse Mercator projection with zones extending indefinitely north and south and 6° east and west, is the basis for both geodetic and cartographic work of the Department of the Defense. For geodetic purposes only, the Lambert and transverse Mercator projections are used as the basis for state plane coordinates in the 50 states.[8] There is one exception to this, the oblique Mercator projection for Southeast Alaska.

34. In order that the survey angles, as measured on the ground, be preserved on the projection, at least with certain limitations, the projection must be of the conformal type. The kinds of projections used by the nations of the world are the Lambert conformal conic, the Mercator in its various forms, and the stereographic projections, all of which are conformal.

35. In choosing a particular projection for a given area certain factors must be considered. If the extent is greater in the north-south direction than in the east-west direction, the transverse Mercator projection is indicated. On the other hand, the Lambert conformal is best for great East-West extent. For areas more or less symmetrical in shape in all directions, the stereographic projection will be the most suitable.

FOOTNOTES

1. Geodesy for the Layman, Aeronautical Chart & Information Center, St. Louis, Mo. (Revised 1962).
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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

C O R R I G E N D U M

Page 1, paragraph 5, line 1, change : "not" to "now".

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КОНФЕРЕНЦИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ
ПО ВОПРОСУ О ПРИМЕНЕНИИ НАУЧНЫХ И ТЕХНИЧЕСКИХ ЗНАНИЙ
ДЛЯ УДОВЛЕТВОРЕНИЯ ПОТРЕБНОСТЕЙ МЕНЕЕ РАЗВИТЫХ РАЙОНОВ

ПУНКТ ПОВЕСТКИ ДНЯ: A.5.2.1

СССР

ОПЫТ ГЕОЛОГИЧЕСКОГО КАРТИРОВАНИЯ И ПОИСКОВ ПОЛЕЗНЫХ ИСКОПАЕМЫХ В МЕНЕЕ ИЗУЧЕННЫХ РАЙОНАХ СОВЕТСКОГО СОЮЗА

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Документы, составленные для Конференции Организации Объединенных Наций по вопросу о применении научных и технических знаний для удовлетворения потребностей менее развитых районов, служат в качестве рабочих документов для этой Конференции. Они опубликованы в том виде, в каком были представлены их составителями, и их содержимое и выраженные в них мнения принадлежат их составителям (см. примечания на оборотной стороне).

ПРИМЕЧАНИЯ

1. Документы, включенные в число материалов, принятых для обсуждения на общих сессиях, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

2. Документы, включенные в число материалов, принятых для обсуждения на специализированных сессиях, будут в распоряжении делегатов Конференции только на одном из этих официальных языков.

3. Резюме всех документов в том виде, в каком они были представлены их составителями, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

4. До открытия Конференции документы и резюме не будут выпущены для общего распространения. Они будут опубликованы заблаговременно только в ограниченном числе экземпляров и исключительно для правительственных делегаций и других правомочных участников. Последующие опубликование и рассылка трудов Конференции будут обеспечены в соответствии с практикой Организации Объединенных Наций, как это установлено ее Издательским комитетом.

ОПЫТ ГЕОЛОГИЧЕСКОГО КАРТИРОВАНИЯ И ПОИСКОВ ПОЛЕЗНЫХ ИСКОПАЕМЫХ В МЕНЕЕ ИЗУЧЕННЫХ РАЙОНАХ СОВЕТСКОГО СОЮЗА

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Практика проведения геологоразведочных работ во многих районах территории СССР показывает, что успех поисков месторождений минерального сырья в значительной мере зависит от состояния, а главное от степени их геологической изученности. Основой геологического изучения, как известно, является планомерно осуществляемое комплексное геологическое картирование.

Геологическое картирование территории СССР было начато в дореволюционный период (до 1917 г.). В то время съемками были охвачены относительно небольшие площади страны преимущественно в районах с установленными перспективами нахождения полезных ископаемых в пределах Донецкого каменноугольного бассейна, Криворожского железорудного бассейна, нефтеносных площадей Кавказа, золотоносных полей Сибири, некоторых рудных полей Урала, Забайкалья и Алтая и т.д. Все эти работы дали возможность не только определить перспективы распространения различных видов полезных ископаемых в экономически важных районах страны, но и подготовить необходимую базу для развертывания горно-эксплуатационных работ.

Объемы выполненных геологоразведочных работ в то время были невелики и поэтому даже основные богатства недр страны оставались почти не раскрытыми. В результате, старая дореволюционная Россия ввозила из других стран многие виды минерального сырья.

В настоящее время благодаря резко возросшей общей геологической изученности территории страны и значительным объемам проведенных геологоразведочных работ мощная промышленность страны полностью обеспечена отечественной минерально-сырьевой базой. При этом ряд видов минерального сырья является предметом экспорта.

Геологические съемки в СССР в значительных размерах стали развиваться после 1928 г. в период индустриализации страны.

Особенно значительного развития геологическое картирование получило по окончании Второй мировой войны (после 1945 г.), в период восстановления и бурного подъема национальной экономики. Современный этап, характеризующийся быстрым ростом промышленного производства, сопровождается дальнейшим увеличением объемов геологосъемочных и поисковых работ. Такое положение объясняется необходимостью быстрого вовлечения в сферу практического освоения все более крупных резервов самых различных видов минерального сырья, необходимых для промышленности и сельского хозяйства не

не только в старых индустриальных районах страны, но также и в менее развитых районах Сибири, Казахстана, Средней Азии, Дальнего Востока и многих других районов СССР, где теперь бурно развивается промышленное производство.

Проведение геологических съемок широким фронтом во многих ранее мало изученных районах потребовало создания наиболее рациональных и эффективных методов проведения работ. При этом необходимо было соблюдать условия, а также сопоставимость получаемых результатов по исследованиям, выполняемым одновременно в разных районах страны. Сложность решения этой задачи определялась исключительно большим разнообразием геологического строения и огромными площадями, равными 22,5 миллионам квадратных километров, а также недостаточной геологической изученностью примерно половины территории Советского Союза, где имелись лишь очень общие представления о ее геологическом строении и еще меньше было данных о возможности нахождения здесь месторождений полезных ископаемых.

Для того, чтобы обеспечить должный научный уровень геологической съемки при наименьшей затрате средств, советские ученые разработали основные требования, которые должны предъявляться к различным типам (масштабам) геологических съемок, а также их последовательности проведения. Было признано необходимым геологическое картирование начинать с мелкомасштабных-рекогносцировочных съемок, на основе которых должны развиваться более детальные геологические съемки масштаба I:200000 и I:50000. При этом было признано необходимым геологические съемки сопровождать поисками полезных ископаемых, так как только такое сочетание обеспечивало быстрое отыскание месторождений минерального сырья и давало возможность, опираясь на достижения современной науки, направлять поиски минерального сырья, добиваясь наибольшего положительного практического эффекта.

В особенно сложных геологических условиях было признано необходимым использовать также геологические съемки масштаба I:500000 при рекогносцировочных геологосъемочных работах и I:100000 и I:25000 при более детальных съемках. При этом учитывалась возможность проведения в ряде случаев геологических съемок крупного масштаба, минуя стадии мелко- или среднемасштабного геологического картирования, если это вызывалось производственной необходимостью, в частности требованиями быстрого геологического изучения районов с выявившимися месторождениями минерального сырья.

Для всех типов (масштабов) геологических съемок и видов поисковых работ были разработаны и введены в действие инструкции и методические руководства, единые для всех организаций, выполняющих геологосъемочные и поисковые работы.

Рекогносцировочные, мелкомасштабные (I:1000000-I:500000) геологические съемки выполняются с целью выяснения общих особенностей геологического строения и выяснения перспектив нахождения месторождений полезных ископаемых.

В течение 12-15 лет вся территория СССР была закартирована в этом масштабе, что дало возможность уже в 1956 г. составить первую сводную геологическую карту м-ба I:2500000 для всей огромной площади Советского Союза, т.е. для одной шестой части всей суши мира, впервые без белых пятен.

Геологическая съемка масштаба I:1000000 явилась фундаментной основой для синтеза геологического строения территории СССР и разработки прогнозов полезных ископаемых, имея в виду, что она сопровождалась систематическими поисковыми работами (прямые наземные поиски, шлиховое опробование и во всех необходимых случаях - отбор шлиховых, штуфных спектро-металлометрических, гидрогеологических, гидрогеохимических и других проб.

При геологических съемках масштаба I:I000000 и I:500000 были выявлены многие новые районы концентрации минерального сырья, а также месторождения различных полезных ископаемых.

В результате этих съемок были получены данные, как правило, достаточные для определения характеристики основных черт минерагении, изученных территорий, что дало основание для постановки целеустремленных более детальных геологосъемочных и поисковых работ. Такими работами прежде всего явились среднемасштабные геологические съемки и поиски масштаба I:200000, которые на протяжении последних десяти лет представляют один из основных видов регионального геологического изучения страны. Они проводятся для установления закономерностей распределения полезных ископаемых, для рационального выбора площадей при планировании поисков полезных ископаемых и геологической съемки более крупного масштаба, для разработки общих вопросов региональной геологии, инженерной геологии, гидрогеологии, а также для решения различных вопросов геологической науки, для составления прогнозных, минерагенических и др. специальных и сводных карт, необходимых для научно-обоснованного планирования геологосъемочных и поисковых работ.

Среднемасштабными геологическими съемками в ближайшие годы будут полностью охвачены все основные горнопромышленные районы страны. При этом всю остающуюся часть территории СССР предполагается ими охватить несколько более чем за I5 лет. Эти геологические съемки, как правило, сопровождаются солидными объемами поисковых работ и, прежде всего, шлиховым, металлометрическим, радиометрическим и другими видами опробования. В последнее время в практику проведения поисковых работ, вопровождающих эти съемки, успешно внедряется магниторазведка, а в необходимых случаях также используются простейшие виды электроразведки.

В равнинных территориях среднемасштабные съемки обычно сопровождаются бурением скважин. В нефтеносных районах они также опираются на сейсмические работы и профили, составленные на основании использования различных видов электроразведки (методы теллурических и магнито-теллурических токов и др.). Все это обеспечивает необходимую "глубинность" исследований и обоснованность рекомендаций по поискам месторождений полезных ископаемых. Во всех необходимых случаях проявления полезных ископаемых вскрываются различными легкими горными выработками.

Такая система работы позволяет ежегодно выявлять в новых, ранее мало изученных районах многие тысячи различных проявлений полезных ископаемых, из которых сотни несомненно заслуживают более основательного геолого-поискового изучения.

Многие районы Казахстана, Алтая, Саян, Тувы, Сихотэ-Алиня, Чукотского полуострова, бассейна Колымы, Кольского полуострова, Сибирской платформы, Енисейского кряжа, Средней Азии и даже районы сравнительно хорошо изученной Украины, уже приобели важное горнопромышленное значение благодаря находкам новых месторождений самых разнообразных видов полезных ископаемых, которые были сделаны при среднемасштабных геологических съемках.

В заслушливых и других районах с дефицитом подземных вод, среднемасштабные геологические съемки, как правило комплексируются с гидрогеологическими съемками, что позволяет одновременно решать также различные вопросы, связанные с использованием подземных вод. В заболоченных и других переувлажненных районах комплексные геолого-гидрогеологические съемки дают возможность решать различные проблемы мелиорации и другие специальные вопросы.

Во многих районах перспективных в отношении нахождения месторождений полезных ископаемых, или в других важных в народно-

хозяйственном отношении районах среднемасштабные геологические съемки и поиски оказываются недостаточными, так как необходима большая детальность освещения их геологического строения. Поэтому в их пределах обычно проводится крупномасштабная геологическая съемка (I:50000-I:25000), основной целью которой является осуществление на основе детального изучения геологического строения перспективных площадей поисков месторождений и выделение участков, заслуживающих постановки на них разведочных работ.

В настоящее время, по мере окончания среднемасштабных геологических съемок объем крупномасштабных геологических съемок значительно возрастает, ожидается, что в течение двух ближайших десятилетий все основные горнопромышленные работы страны будут обеспечены этими съемками, что позволит вовлечь в промышленное освоение сотни новых месторождений полезных ископаемых. Крупномасштабные геологосъемочные и поисковые работы по сравнению с среднемасштабными работами обеспечиваются значительно более плотной сетью геологических наблюдений. Кроме того, они сопровождаются значительно большими объемами горных и буровых работ, а также использованием различных видов геофизических исследований. В ряде районов и особенно с широко распространенным чехлом рыхлых отложений, выполняемые работы приобретают характер геолого-геофизических съемок, сопровождающихся картировочным и поисковым бурением.

Геологическая эффективность этих работ, как правило, высокая. В результате их выполнения, ежегодно вводится в разведку несколько десятков новых месторождений полезных ископаемых и при этом во всех необходимых случаях решаются различные гидрогеологические вопросы. В районах угольных, а также ряда других месторождений неметаллических полезных ископаемых пластового типа эти съемки оказываются достаточными для определения заключенных в недрах перспективных запасов (категория C_I), подсчет которых может быть выражен в тоннах.

В связи с тем, что запросы промышленности в отношении тех или иных полезных ископаемых с течением времени меняются, ранее закартированные в крупном масштабе площади иногда вновь вовлекаются в геологическое изучение с целью дополнительных поисков или ревизионной оценки ранее выявленных проявлений полезных ископаемых. Выполнение этих работ значительно облегчается в связи с тем, что поиски производятся на уже готовой геологической основе и при наличии значительно разработанных поисковых критериев, что позволяет лучше выбрать рациональную систему поисковых операций и обеспечить их соответствующими техническими средствами.

Процесс общего геологического изучения обычно завершается детальными съемками масштаба I:10000-I:5000, которые, как правило, ставятся на площадях ранее выявленных месторождений полезных ископаемых. С помощью этих съемок выясняется геологическое строение месторождений, оконтуриваются залежи полезных ископаемых, выясняются гидрогеологические и многие другие вопросы, необходимые для промышленной оценки месторождений и связанных с этой оценкой подсчетом запасов минерального сырья.

Геологические съемки всех масштабов во всех необходимых случаях сопровождаются различными видами специальных съемок геофизических, геохимических, гидрогеологических и инженерно-геологических, а также тематическими исследованиями (стратиграфическими, палеографическими, петрографическим, литологическими и т.д./. Использование этих видов работ позволяет значительно расширить изучение материалов геологических съемок, как для решения разнообразных практических, так и научных вопросов.

Характерной особенностью геологического картирования, выполняемого в последнее время, является широкое использование материалов геофизических (аэромагнитных, гравиметрических и, нередко, также сейсмических, электроразведочных и др.). и геохимических исследований, которые дают возможность более полно изучать глубинное и геологическое строение с площадей, вовлекаемых в геологическое картирование для того, чтобы обеспечить не только большую достоверность прогнозов нахождения минерального сырья в недрах земли, но и вести целеустремленные поиски месторождений, не выходящих на земную поверхность.

Весьма существенное значение при этом имеют материалы аэрофотосъемок, которые позволяют с наименьшей затратой средств гораздо более детально проводить геологические съемки и уверенно направлять многие виды поисковых работ.

Неотъемлемой частью геологических съемок, особенно тех из них, которые охватывают большие площади, является систематическое обобщение накапливающегося геологосъемочного материала в виде обзорных и сводных карт различных масштабов: для СССР в целом масштаба I:1000000-I:2500000, для крупных районов в масштабе I:500000-1600000; для районов концентрации полезных ископаемых в масштабе I:200000 и крупнее. Такое обобщение позволяет корректировать различные геологические построения, а также создавать необходимую базу для карт полезных ископаемых и прогнозно-минералогических карт, приобретающих в последнее время все большее значение для научного обоснования поисков минерального сырья, а также для достоверной прогнозной оценки его запасов.

По мере развития геологических работ, используемые методы довольно быстро совершенствуются и значительно расширяются возможности поисков в связи с широким внедрением в область классической геологической съемки новейших геофизических, геохимических, биостратиграфических, палеографических и других видов исследований, что оказывается возможным благодаря той мощной поддержки, которая систематически оказывается геологической съемке многими научно-исследовательскими геологическими институтами страны.

Проведение значительных объемов геологосъемочных, геофизических и поисковых работ дало возможность выявить только за последние I0-I5 лет в ранее мало изученных в геологическом отношении восточных районах страны новые крупные минерально-сырьевые базы нефти, газа, железных руд, цветных металлов, алмазов, золота и многих других полезных ископаемых.

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NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

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RIVER BASIN PLANNING IN THE UNITED STATES

by

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1. River basin planning, as we know it in the United States today, is a product of over a century and a half of experience in adapting fast-growing human occupancy and economic activity to the great complex of land and water resources of the nation. In the early years of our country, we had to deal with much the same problems now faced by the developing nations--problems of economic growth and nation-building in the context of a rapidly growing population.

2. In the earliest efforts to expand beyond the Eastern Seaboard, the primary emphasis was on development of the rivers for navigation.[1] With increasing settlement of the Mississippi Valley, major problems of flood protection arose. By 1900, settlement of the arid and semiarid lands of the West required development for irrigation. To these needs were soon added demands for hydroelectric power and for improvement of the quantity and quality of water supplies. Then, a philosophy of integrated, multiple-purpose river basin planning was formulated as part of a national conservation movement. It was expressed in remarkable complete form in the 1908 report of the Inland Waterways Commission.[2] Finally, when lagging economic activity provided added incentive in the 1930's, the Federal Government assumed major responsibilities for river basin development and intensive planning was begun, resulting in the preparation of plans, at least in outline form, for most of the major river basins of the nation.[3]

3. In the discussion to follow, we present first the basic concept of integrated river basin planning and an idealized methodology for the conduct of such planning. Following this statement on the substance of planning, we examine United States experience in planning during the past 30 years and present some important implications for the developing areas of the world. We shall distinguish those elements of our experience that embody principles of general applicability from those unique to the United States.

Basic Concept of Integrated River Basin Planning

4. The concept of integrated river basin planning, as generally understood in the United States, has two major elements: (a) the multiple use of individual units of river systems, especially multiple use of reservoir storage; and (b) the treatment of the river basin as a hydrologic and physiographic unit.[4]

(a) Multiple-purpose use involves the planning and operation of projects, especially storage reservoirs, to serve all of the needs which the project can be designed to meet, to the full extent that this can be done advantageously, as compared with the cost of single-purpose or other alternative ways of meeting the various needs.

(b) Treating the river basin as a hydrologic and physiographic unit permits proper consideration of the interrelationship of all streams in a basin, the associated ground water, the effects of forest and ground cover, and all land-water relationships pertinent to development and use of the basin's resources. It does not

preclude taking into account, in the planning, the needs or effects outside the basin which are pertinent to optimal use of the basin's resources.

Methodology for River Basin Planning

5. In general terms, the methodology of river basin planning in the United States consists of four steps:[5]

(a) Setting the broad objectives for development. These may be: increase in national income; economic growth; or increase in productivity and income of certain sectors of the economy, specific classes of individuals, or residents of particular regions. This step is generally the task of top policy-makers--the Executive and the Legislature.

(b) Translating the broad development objectives into criteria for use by river basin planners to formulate specific plans. This step includes a delineation of the planning region--the river basin, group of basins, or other region for which a water resource plan is to be prepared. These tasks of criteria-setting are functions for the central policy and planning group of the Executive, with oversight from the Legislature.

(c) Formulating the optimal river basin plan and schedule of development (or alternate plans and schedules) at the local or field level, in terms of these criteria, by choosing from among the many combinations of alternative water control structures and kinds of water-derived products and services. This central core of the planning task is generally carried out by a river basin planning staff given specific responsibility for the purpose.

(d) Review of the proposed river basin plan and proposed schedule (or alternative plans and schedules), and reconsideration of the appropriateness of the objectives and planning criteria in the light of the new information obtained from the completed plan. This step (which comes full circle to Step (a)) is the joint task of the Legislature and the Executive with his central policy and planning group.

6. Often the third step--the field-level planning task--is considered to be the whole of basin planning. Yet, without over-all objectives and without specific guidance on criteria for planning or an assessment of the over-all consequences of a river basin plan, field-level planning would take place largely in the dark. All four steps are essential parts of a valid planning methodology.

7. However, the third step is the heart of the technical planning process. Here we examine further its major elements, of which there are, broadly, three:

(a) Identifying and measuring the physical, economic, and social problems and requirements of the region (in relation to the established broad development objectives) that water resource development can help to solve or meet. This includes making projections of regional population, economic activity, and demands for water-derived products and services under various assumptions of the extent and nature of water resource development.

(b) Identifying and measuring the various opportunities for control and development of the region's water and related land resources to help meet the needs and solve the problems identified in element (a) above.

(c) Given the schedules of demand for water-based products and services, and the opportunities for meeting the demands through water development (where demands are related to the established objectives), the formulating of an optimal water development plan, including a schedule of development. This can be accomplished through systematic analysis of many alternative plans under a procedure that seeks to select successively better and better plans (where improvement is measured in terms of the preassigned objectives of development) until no further improvement can be made. In some cases, alternative plans are developed to meet different mixes of objectives.

8. In the United States, benefit-cost analysis has been highly developed as the basic tool in this process of formulating optimal plans and selecting from among alternatives. The estimated cost of the development plan under review is compared with the estimated benefits, both usually expressed in market value terms. The object is to devise the plan with the greatest excess of benefits over costs. In

general, a plan is not recommended for development unless the ratio of benefits to costs is greater than unity. Although benefits and costs are usually expressed in terms of increases in national income, they can be (and often are) expressed in other terms as well, such as income gains to special groups or regions. Intangible factors--both benefits and costs--are taken into account in the analysis, and are often given implicit weights in monetary terms.

United States Experience and its Implications for Developing Areas

9. Over the past 30 years, the United States has invested about $30 billion in developing its river basins. These developments have varied from relatively small-scale projects, often for a single purpose, to large-scale, complex, multi-purpose undertakings such as the Tennessee Valley development and the major dam and reservoir systems in the Columbia and Missouri basins. From the experience of planning and carrying out these developments, there emerge some generalizations, insights, and principles that should be helpful to others just now starting the planning and development process. Our discussion of United States experience is presented in terms of three major aspects of the planning process: defining goals and objectives, formulating the river basin plan, and organizing and staffing for planning. Brief mention is also made of the problem of basic data for planning. (Although much of the planning, financing, construction, and operation of water resource developments in the United States, particularly hydroelectric power and water supply, has been accomplished by private initiative and local governments, our discussion is centered on comprehensive, multiple-purpose river basin planning, which has been carried out primarily by the Federal Government in cooperation with the States. We omit any discussion of the impact on United States river basin planning of the issues of private versus public development. Although such issues have had important effects on our experience, they are so closely tied to our institutional pattern that few meaningful lessons can be drawn for application elsewhere. For treatment of this aspect of the subject, the reader is referred to the references contained in the footnotes, especially footnotes 2, 3, 6, 7, 8, 16, 18, and 23.)

Defining Goals and Objectives for River Basin Development

10. The most successful river basin developments in the United States have taken place under circumstances where there was general understanding and acceptance of the goals to be attained. Our first fully-integrated river basin development--the Tennessee Valley system--was begun under particularly favorable circumstances in this respect. The Congressional Act of 1933 establishing the Tennessee Valley Authority gave the agency a broad mandate to promote the economic growth of the region through resource development--in particular, through exploiting the navigation and hydro-power resources of the river systems and the fertilizer resources of the region. This general directive was given detailed substance during the formative years of the TVA, but the clear-cut regional development objective which the TVA had from the start allowed the agency to proceed with integrated planning and development in an effective way.[6]

11. Similarly, the large-scale development of the Columbia River basin first began with stimulation of regional employment and economic growth as the major objectives. Bonneville and Grand Coulee dams, although multiple-purpose in concept, were noteworthy because of the large quantities of low-cost hydro-power which they provided. These dams, started in the 1930's and completed in time to make a major contribution of hydroelectric energy to wartime industrial production, were followed by other hydro projects after World War II. Regional development of the Pacific Northwest, primarily through exploiting the hydro-power resources of the Columbia River, but also through navigation, irrigation, flood protection, and other resource development, remains an important goal of public policy today.[7]

12. In partial contrast, the Missouri River basin development did not proceed with so general an agreement on goals and objectives. Although the broad goal of the 1943 Missouri basin development plan was regional economic stabilization and growth, in fact the upper and lower portions of the basin had quite different economic

and resource problems. The solutions to these imposed conflicting demands upon the river system. As a result, compromises were necessary to meet both navigation and flood control needs of the lower basin and a reasonable development of the irrigation and hydro-power recources of the middle and upper basins. Because these compromises did not fully resolve the basic conflicts in demand, problems in allocating the limited available water resource have persisted into the operation stage. [8]

13. Comprehensive planning studies undertaken since World War II have attempted to deal with the problem of goals and objectives in a more systematic way. In this the studies have been only partly successful. In studies of the New England States and of the Arkansas-White-Red river basins of the Southwest, completed in the early 1950's, regional development as such was not the central objective. Rather, emphasis was placed on the contribution that water resource development could make in meeting needs for water-derived products or services arising from the normal economic growth of the region. However, detailed projections of economic activity were not made for these regions; hence it was not possible to estimate future water resource needs in any detail. The results of these surveys were thus presented in terms of inventories of possible water-development projects, rather than in terms of firm water resource development plans with associated time schedules.

14. In more recent studies of the Delaware, Potomac, Southeastern, and Texas River basins, attempts have been made to project regional population and economic activity over a 50-year period to serve as guides for estimating demands for water-related products and services. Although these projections can serve only as rough indicators for the pattern and magnitude of future water demands, they provide a logical and consistent basis for setting forth a plan of water resource development in which individual projects can be scheduled over time and uses can be shifted to accommodate changing demand patterns. In fact, the water-development plan for the Delaware River basin, completed by the Corps of Engineers in 1960 in concert with other Federal and State and local agencies, presents a schedule of site reservation and project construction to meet the projected domestic and industrial water supply needs of the region to the year 2010. [9]

15. Most recent improvements in planning technique relating to goals, objectives, and economic projections are twofold:

(a) River basin planning standards and criteria have been revised in 1962 to emphasize the need for clearly defining the over-all goals or objectives of river development, and to distinguish among goals where conflicts are likely to arise. Thus, the objective of increase in national income is to be distinguished from objectives such as regional economic growth or increasing the income of specific classes or groups of individuals. [10]

(b) Increased emphasis is being given to improving techniques of projecting regional population and economic activity, based upon a single set of national economic projections which is to be periodically revised.

16. Lessons for developing areas may be drawn from the above. Goals and objectives need to be clearly stated by top policy-makers at the start of the planning process. Ideally, these should be consistent for all subnational river basin planning groups. Over-all national projections of economic activity--which may be goals or targets in some developing countries--should be developed, and regional or local projections derived from these should serve as guides to regional or local planning groups.

Formulating River Basin Plans

17. Because the methodology of formulating river basin plans is the product of gradual evolution over the past half-century, our experience can appropriately be described by citing a number of landmark studies. These are merely illustrative, as the present art and science of planning is the composite result of the labors over the years of thousands of engineers and physical and social scientists.

18. One of the best early examples of orderly and systematic planning for an entire river basin is the development plan of the Miami Conservancy District for the Miami River basin in Ohio. Although oriented toward but a single purpose--

flood control--a rather sophisticated methodology was used to examine a large number of alternative combinations of reservoirs and levees in the search for the least costly means of achieving a given physical objective. [11]

19. The inventory surveys of major United States river basins, executed by the Corps of Engineers in the late 1920's and early 1930's, produced a number of significant framework plans consisting of combinations of storage reservoirs designed for flood control, navigation, hydro-power, irrigation, and domestic and industrial water supply. The comparisons of alternatives and economic analyses were not carried out in great detail. Yet it is noteworthy that these inventory surveys formed the basis of much of the river development work of the 1930's and even later years. [12]

20. Building on the Corps of Engineers inventory survey of the Tennessee River basin (which was one of the most detailed and complete of the group), the Tennessee Valley Authority enlarged and refined the plans for the basin as the agency proceeded with its development. Many new insights into the relationships of river system structures and uses were gained in the planning, construction, and operation of this first fully-integrated, multi-purpose river basin development. [13]

21. The art of plan formulation was advanced on other fronts during the late 1930's and the 1940's. The Water Resources Committee of the National Resources Planning Board stimulated comprehensive, multi-purpose planning through Federal-State-local drainage basin committees in all of the major river systems of the country. Also, in 1941, this Committee prepared a statement of national water policy which contained an excellent prescription on river basin plan formulation. [14]

22. By 1950, the principles of integrated planning of river basin developments had been worked out in considerable detail. Following the work of the National Resources Planning Board, a Federal interagency committee had developed an excellent statement of the principles and procedures of economic analysis for application to river basin planning. [15] Yet practice lagged behind principle. Most river basin plans were mere inventories of unrelated projects. Plans were typically oriented to one or two major purposes--flood control and navigation in the case of Corps of Engineers, irrigation in the case of the Bureau of Reclamation--with other uses considered only as incidental. Detailed comparisons of a large number of alternative combinations and detailed optimization studies were the exception rather than the rule. But the decade of the 1950's was nevertheless a period of major advance. The principles and practices of comprehensive planning were given renewed emphasis in the studies and reports of three Presidential Commissions--the Water Resources Policy Commission, the Missouri River Basin Survey Commission, and the Advisory Committee on Water Resources Policy. [16]

23. This period also saw a significant increase in the interest of academic scholars in river basin planning and development problems, especially in economic evaluation. For some years prior to this, a small but growing group of academic economists, largely in the western states, had been giving attention to these problems. [17] Since 1955, a number of significant works have appeared whose impact on planning is only now beginning to be felt. These studies deal principally with the economics of water resource planning and development. They analyze current agency practices in the light of economic principles and suggest various prescriptions to be followed in plan formulation and choice among projects. Although these books and the related work of academic scholars do not provide consistent sets of rules to follow in plan formulation, they give much more detailed treatment to the problems than was available heretofore. [18]

24. The most recent planning experience in the United States has begun to reflect the influences of these movements for improvement both within and outside the Federal Government. Recently completed studies of the Delaware and Potomac River basins, and of the Texas streams, are much more comprehesive in scope than previously was the case. [19] The Delaware River Basin Plan, recently prepared by the Corps of Engineers in cooperation with other Federal agencies, the four States concerned, and local agencies, is a good example of a major advance toward fully comprehensive river basin planning. The basin, covering an area of about 13,000 square miles, has a relatively high population density and degree of urbanization

and industrialization, with a strong further trend in this direction. Projections of population and economic activity in the basin and adjacent areas, to the year 2010, were made for use in defining needs for water-based products or services. A wide range of possible measures to satisfy the needs was considered, including improved land management, local flood protection works, reservoirs of various sizes, flood plain zoning, water quality and ground water control, and a salt water barrier in the Delaware River estuary. A total of 193 major and 386 small reservoir possibilities was considered in formulating the final plan, consisting of 19 major and 39 minor water control projects. Another feature of the plan was the proposal for early acquisition of reservoir site lands in order to preserve them for future use in this densely populated area. [20]

25. There is increasing concern with fundamental research in the process of river basin planning, both by the planning agencies and by university and other outside research groups. The basin research on river system planning, initiated at Harvard University in 1956, has now moved toward the application stage. [21] A number of other universities are now turning to research in this field. The work done to date indicates that the analytical approaches loosely grouped under the terms "operations research" or "systems analysis" can be adapted to the planning of river basin developments by taking advantage of the high-speed computation capabilities of electronic computers. These approaches allow the testing of many more combinations of purposes, project units, and scales of development than was possible under previous techniques. Presently undergoing an extremely rapid evolution, but already available in a form suitable for use in connection with the problems of developing nations, these systems analysis techniques appear to have many promising applications in planning and programming of water and related land resource development. [22]

26. The implications of United States experience in plan formulation can be summarized as follows:

(a) Of prime importance is the way in which the planning problem is set up. We are only now learning the importance of clearly setting forth the objectives to be achieved, of developing planning standards and criteria that flow from these objectives, and of using a methodology to prepare optimal plans in terms of the standards and criteria. When the problem is set up in this way, the respective roles of top policy-makers, central office planners, and river basin technicians in the field emerge clearly. In setting up the task of field-level planning, it is important to view it in comprehensive terms, to include within the purview of planning all relevant purposes and all reasonable means and measures (structural and non-structural) of accomplishing the purposes. The dynamic nature of water resources investment must be recognized; scheduling of investment becomes an integral part of the choice of project and purpose mix. In examining the many alternative river basin plans, a systems approach should be used that takes into account the technological elements of (1) multi-purpose use of water control structures, (2) hydrologic and physiographic unity of river basins and surface-ground water complexes, and (3) the interrelations between the land resource and surface and ground water flows. Analysis of alternative plans should be not in terms of physical outputs alone, or even primarily, but should be framed in economic terms. It is here that United States experience with benefit-cost and systems analysis can be useful.

(b) Benefit-cost analysis in monetary terms can serve as a base for weighing intangible considerations. Alternative plans that include provisions for achieving non-economic objectives can be compared with plans which are optimal from an economic standpoint. Such comparisons provide a valuable aid to judgment on the extent to which a departure from the economically optimal solution is warranted in the interest of attaining or preserving intangible values.

(c) Planning river basin developments should be considered as only a part of total investment planning for all sectors of the economy. This proposition follows from (a), for if the water investment planning task is set up in terms of meeting broad national objectives, it will need to be adapted to the total investment program. De-emphasis of physical results or outputs will serve to remind decision-makers that engineering structures, no matter how grand or impressive in scale of design, are not ends in themselves, but are means toward serving human needs.

Organizing and Staffing

27. The problem of organizing for effective planning of river basin development covers a wide spectrum. Some river basins may lie in an area under the political and managerial control of a single entity. Here the problem would be reduced to assembling and managing the necessary skills. More often, a river basin spans more than one political jurisdiction and involves more than one agency having technical or managerial responsibilities. Also, the political jurisdictions may include more than one national sovereignty. In the United States, river basin planning experience has embraced the entire range from single-entity control to multi-agency, multi-political and even international jurisdictions.

28. Agency functions. Some of the agencies have already been mentioned in the previous discussion. A more complete catalogue is presented below.

29. Planning for the use of rivers for inland navigation is the responsibility of the Army Corps of Engineers, a Federal agency. Flood control planning is also carried out primarily by agencies of the national government--the Department of Agriculture working on upper watershed protection in cooperation with local soil conservation and watershed districts organized under State laws, and the Army Corps of Engineers which plans major reservoir control and other flood protection measures. Large-scale irrigation planning in the West is assigned to the national government's Bureau of Reclamation in the Department of the Interior. This Department also has power marketing responsibility for hydroelectric energy generated at Federal water projects, and nationwide responsibilities for assembly of basic hydrologic data, geologic surveys and topographic mapping, and survey, research, regulatory, and management functions for minerals, public lands, national parks, fish and wildlife resources, and outdoor recreation. The Department of Agriculture also has major forestry research and management responsibilities. In general, State governments also have numerous agencies concerned with this range of functions.

30. Providing domestic and industrial water supplies is primarily the responsibility of individual communities, local water districts, and the States, but the Public Health Service in the Federal Department of Health, Education, and Welfare has survey, research, and regulatory responsibilities for water supply and control of pollution. Several other Federal agencies have authority to help in developing water supplies and improving water quality.

31. Other agencies of the central government actively concerned with river basin planning include the Federal Power Commission and the Department of Commerce.

32. In addition to the numerous Federal agencies involved, the States, interstate and intrastate agencies, and local interests, both public and private, often have a significant role in the planning process. Some States, notably California, have sizable planning and development agencies of their own. In recent years, participation of the States in river basin planning has increased significantly.

33. The great range of interests involved in a modern river basin study has led us to experiment with various integrating or coordinating devices. The Tennessee Valley Authority was such an experiment, in this case giving almost all national planning and development authority to a single regional agency, but leaving State and local authorities relatively untouched. Informal Federal interagency committees, with State participation, were set up in the Missouri and Columbia River basins, and special planning committees or commissions with Federal agency and State representation have been used in the Arkansas-White-Red basins, New England-New York region, and the Texas and Southeast river basins. In other cases, such as the Delaware and Potomac basins, a single Federal agency, the Corps of Engineers, has taken the leadership in planning, with participation from other Federal and State agencies through committees. A Federal-State commission has recently been established by interstate compact to guide further planning and development in the Delaware basin.

34. None of these arrangements has proven to be fully satisfactory or universally applicable in the United States. There is now before the Congress a proposal by the President to establish Federal interagency planning commissions with State participation, as required, for all major river basins. [23]

35. Although United States experience with organizing for planning is specialized and unique, one generalization emerges. So many different interests--national, regional, and local, public and private, rural and urban, agricultural and industrial--impinge on the planning process, that no single planning agency can have purview of all of them. Thus, in developing countries as in the United States, coordinating arrangements and devices will still be necessary, even when the core task of preparing the river basin plan is assigned to a single agency with broad responsibilities.

36. The international aspect. The United States has entered into formal arrangements affecting river basin planning with both of its adjoining neighbors, Canada and Mexico. The International Joint Commission, United States and Canada, is a permanent body to which the two countries may refer problems of mutual concern for study and recommendation. This agency provides the structure through which the appropriate agencies and interests in each country can deal with problems of planning for development of rivers that cross or form the boundary or that flow into or out of boundary waters. [24] The International Boundary and Water Commission, United States and Mexico, was formed to administer the development of certain specific projects and to prepare plans for additional development on rivers of mutual concern. [25]

37. On the whole, both arrangements have worked well. The organizations have been used effectively for coordinating the collection and analysis of basic data, as well as planning and development activities. They have demonstrated the feasibility of two different arrangements for planning: one through the use of established organizations in each country; and, the other, through the use of a special organization administered by representatives of each country. The experience of these organizations with a wide variety of problems may well prove useful to other nations involved in international river basin planning.

38. Staffing for planning and development. As river basin planning grows in complexity and scope, and as closer coordination of separate governmental jurisdictions and agency functions is required, an approach based too exclusively on narrow technical disciplines is far too restrictive. We have found that modern river basin planning requires the application of the talents and skills of many disciplines. The lesson for developing nations is clear. Staffs for river basin planning should be composed of an interdisciplinary team, including not only a wide variety of types of engineers and physical scientists, including civil engineers, hydrologists, meteorologists, geologists, agronomists, soil scientists, and biologists, but also experts in economics, geography, mathematics, sociology, social psychology, political science, law, statistics, and management and administration, among others. In addition, in less-developed nations, the river basin plan should include projections of needs for professional and skilled manpower to carry out the plans and to use the completed facilities, and definite proposals for meeting these manpower needs.

Basic Data for Planning

39. In this brief summary on basic data, we assert that our early experience with basic data for river basin planning will very likely be duplicated by many developing nations. Those who undertook the first comprehensive surveys in the United States had to contend with great gaps and serious inadequacies of basic physical data. Yet, some highly successful developments were undertaken in spite of these handicaps. Fortunately, the importance of systematic collection and analysis of basic physical and economic data has won increasing recognition in this country, so that our situation in this respect is much improved. In a sense, planners will always feel that the available data are not fully adequate for the task at hand. [26]

40. Several suggestions flow from our experience with basic data for planning:

(a) Once the major gaps and inadequacies in basic physical and economic data have been identified, major efforts should be made to institute programs for the systematic and sustained collection and analysis of such data.

(b) Unless available data are very scanty, it is usually possible to do a good deal of planning on a reconnaissance basis, to prepare framework plans that are useful as general guides to development.

(c) It is prudent, however, to avoid heavy commitments of investment in the face of grossly inadequate data. An expedient solution is to resort to construction of river development works in stages and to incorporate flexibility of use into such works, so that shifts in use can be made at moderate cost as required in the future.

CONCLUSIONS

41. This brief review of United States experience in river basin planning has revealed several significant implications of possible interest to developing countries. In recapitulation, the important points are:

(a) Goals and objectives for river basin development should be clearly stated by the top policy-makers at the outset of planning.

(b) Over-all national projections of economic activity or targets for economic development should be established, and regional or local projections or targets should be derived from these as guides for the planners.

(c) The key to successful planning is the manner in which the planning task is set up: planning standards and criteria must flow from the over-all objectives, and a methodology for optimization in terms of these standards must be developed.

(d) Benefit-cost analysis is a useful basic tool for formulating economically optimum plans, and it can be used to evaluate intangible effects as well as effects measured in monetary terms.

(e) Planning river basin development should be considered in the context of total investment planning for all sectors of the economy.

(f) Even river basin planning agencies with very broad mandates and considerable autonomy will find it necessary to set up some type of coordinating arrangements with other central and local governmental units to take account of the diverse interests involved.

(g) A broad, interdisciplinary-team approach is essential to effective planning for comprehensive river basin development; definite provision should be made, in river basin plans, for providing the varied and specialized skills needed to carry out the plans.

(h) Programs for systematic and sustained collection and analysis of basic data are an integral part of the task of river basin planning; where data are seriously lacking, broad plans with provision for flexibility are preferred over plans in great detail.

42. In considering these points, it is well to note possible differences between the planning environment in the United States and in developing countries:

(a) In the United States, river basin development is still an important factor, but not necessarily a dominant one, in advancing the economic development of specific regions or of the country as a whole; whereas in developing countries, development of river basin resources may be a key factor and may merit a large portion of the national effort for economic progress.

(b) In the United States, development has proceeded to a point where needs for improving water quality for many purposes, for enhancing fish and wildlife environment, and for developing recreation opportunities have come to be of equal and sometimes controlling significance in planning river basin developments; whereas in developing countries, the needs for basic economic development in agriculture or industry may warrant greater emphasis, initially at least, on such water uses as irrigation, hydro-power, navigation, or flood control.

(c) In the United States, it has been possible to place great reliance on market prices for computing development costs and benefits, because: (1) markets are highly developed for a great range of inputs and outputs, (2) outputs of commodities or services flowing from water development plans do not comprise so great a proportion of total output as to affect market prices significantly, and (3) constraints on foreign exchange have not been a significant factor. In developing countries, variations in these conditions should be considered in evaluating river basin developments.

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20. See Footnote 9.

21. Results of the first, basin-research stage are reported in Maass, A. A. and Hufschmidt, M. M., et al., referred to in footnote 5.

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United States of America

DESALINATION; EVAPORATION REDUCTION: ARTIFICIAL PRECIPITATION; LARGE-SCALE WEATHER AND CLIMATE MODIFICATION

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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DESALINATION; EVAPORATION REDUCTION; ARTIFICIAL PRECIPITATION; LARGE-SCALE WEATHER AND CLIMATE MODIFICATION

by

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1. The earth's total water supply is enormous compared with the needs of mankind; only the extreme variation of its availability with time and place causes water shortages. Rain and snow falling on land areas amount to 33,000 cu.m. annually for each inhabitant of the globe. This is more than ten times the generous use of water by North Americans for all purposes, including irrigation.

2. Average figures on water supply are of little comfort to the peoples of arid lands, or to a farmer in Kansas in a year of serious drought. Rainfall averages less than 30 cm. annually (45 percent of the average for all land areas) on more than half the land surface of the earth. This is less than the average rainfall in such places as Mogadiscio, Somalia, where fresh water is in short supply.

3. Great engineering works designed to impound and distribute water, conservation measures, and multiple re-use of water can do much to offset shortages, but in many arid regions these measures will prove inadequate. Science and technology must provide ways to increase water availability.

DESALINATION

4. One obvious way to increase water availability is to recover fresh water from the enormous and widely-distributed supplies of sea water and of brackish water. Large underground stores of brackish water are located in many arid regions remote from the sea.

5. Research is being carried out in many countries for the purpose of developing practical desalination processes. Much of the work being done in the United States is coordinated and supported by the Office of Saline Water of the Department of the Interior.

6. Of the many desalination processes studied, only distillation and freezing for sea water, and electrodialysis for brackish water are now commercial[b]--commercial in the sense that they are promoted by industrial concerns. These and one other

a. Dr. Wexler had completed a revised draft of his section of this paper just before his death on August 11, 1962. His colleagues of the U.S. Weather Bureau believe that the revised draft which is reproduced here substantially expresses Dr. Wexler's intended contribution.

b. Ion exchange resins and zeolites are used to soften water, but are too expensive for the desalination of even moderately brackish water.

will be described briefly; reference 3 provides a bibliography on the subject, and references 4, 5, 6 and 7 describe recent research and development studies of a number of processes.

Multiple Distillation

7. The oldest and most used process is distillation. Total installed capacity of sea-water distillation plants is upwards of 80,000 cu.m. per day. The installations must be large and expensive if the needed energy is to be used economically.

8. Approximately 600 cal. are required to produce one gram of fresh water by simple distillation of sea water, but the great technical invention of multiple-effect distillation makes it possible to reduce this to 60 cal., or even less. Variations of the basic process include multiple-flash distillation (requiring heat transfer surface to condense vapor, but not for boiling) and vapor recompression (requiring electricity in place of heat energy). Studies indicate that for large plants it may be economical to supply the heat required by means of specially designed nuclear reactors.

Solar Distillation

9. Solar stills have received considerable study and development, as they serve to provide small quantities of water at moderate cost. Solar distillation is not a different desalination process, but a way of using solar radiation to eliminate the cost of fuel.

10. Though the energy is free, the first cost of glass-covered stills is high in relation to capacity for producing water. Current studies of inflated plastic stills may lead to less expensive designs. In the many regions of the world where the incident solar radiation averages 540 cal. per sq. cm. per day, these stills can produce 1200-1600 litres of fresh water annually from each square metre of ground area. They are being used in increasing numbers in arid regions, and have been produced commercially in Algiers and in Australia.

11. The cost of solar stills in relation to capacity is high because the solar radiation intensity is so low. To produce water at a rate equal to the withdrawal and use in North America would require single-effect stills covering an area one-quarter as large as the area of the cultivated land (4% of the total area of the U.S.).

12. It seems unlikely that solar stills can compete with large multiple-distillation units in the production of water at low cost. Solar stills can be expected, however, to find wide use in converting sea-water or inland brackish water to supply the fresh-water needs of small living groups in many arid regions of the developing countries.

Freezing Processes

13. If saline water is partially frozen and the ice crystals washed free of residual brine, the ice may be melted to produce fresh water. In one variation of the process an immiscible hydrocarbon liquid is dispersed in the saline solution; vaporization of this material provides the refrigeration to cause the water to freeze. In another process a solid hydrate is formed by contact of water and propane or other hydrate-forming substance. These solid hydrates form at temperatures greater than that at which water ice separates, and the cost of refrigeration is less.

14. Performance data on commercial desalination plants employing freezing processes are not yet available, but engineering studies suggest that freezing may be competitive with multiple-distillation for large desalination plants. One of the desalination plants to be constructed by the Office of Saline Water, U.S.D.I., will employ a freezing process. Evidently, the major process problem is the design of an efficient device to wash away residual brine from the partially-frozen mass of very fine ice or hydrate crystals.

Electrodialysis

15. This process employs membranes in the form of thin sheets of highly-hydrated organic polymers. The ion fragments of salts in solution are caused to pass through these membranes, but passage of water does not occur.

16. In contrast with distillation or freezing processes, electrodialysis consumes (electrical) energy roughly in proportion to the salt removed, rather than to the fresh water produced. For this reason, electrodialysis is more economical for the desalination of brackish than of sea water.

17. Electrodialysis is now a commercial process, and a number of plants ranging in capacity from a few hundred to 11,000 cu.m. per day have been installed in various parts of the world. Two towns in the United States employ electrodialysis of brackish water to provide municipal fresh water. Plants of this type would appear to have wide application in many arid regions where quantities of brackish water are available.

Ultrafiltration

18. This process, also known as "reverse osmosis", is not now commercial, but is the subject of considerable research in the United States. It employs thin membranes which permit the passage of water, but not of salt, when a pressure of more than about 23 atmospheres is applied (as by a piston) to sea water on one side of the membrane.

19. Too little is known about the mechanism of the membrane process to permit the selection and manufacture of useful osmotic membranes. Though promising results have been obtained, practical membranes will probably not be developed by trial and error; the basic physics of the process needs to be understood.

Desalination Costs

20. Actual data on costs of large-scale desalination operations are quite fragmentary. Sea water plants built ten or more years ago produced fresh water at costs of $0.79 - $1.27 per cu.m. Recent commercial plants report costs of $0.33-$0.53 per cu.m. These are total costs, including fixed charges, as would be calculated for an industrial enterprise. One electrodialysis plant of medium size is said to desalinate a 2200 ppm. brackish water at a total cost of $0.12 per cu.m.

21. Though the trend of costs has been downward, the curve would seem to be approaching an asymptote somewhere in the range $0.08 - $0.13 per cu.m. for the large-scale desalination of sea water with present energy costs. Though clearly a matter of opinion, it does not now appear that further engineering refinements of present commercial schemes can lead to sea water desalination costs in the range of present U.S. prices charged for irrigation water--generally less than $0.02 per cu.m. A new combination of scientific principles and technical inventions is needed, or alternatively a marked reduction in the cost of energy.

Prospects for Large Cost Reductions

22. From the foregoing, it is clear that desalination costs are now high, and that present commercial processes will find application only in rather special situations. It is of interest to speculate as to the possibilities that much less expensive processes can be developed.

23. Thermodynamics provides a basis for such a speculation. The theoretical (minimum possible) work energy required to separate one cubic metre of fresh water from sea water at 25°C., leaving a brine containing the same amount of water, is 1.09 kwh. This has a value of only about $0.01. It is worth asking why present desalination costs for sea water are 30 to 50 times this figure.

24. Part of the answer is that energy represents but a fraction of the total costs, but reduction in the energy required would lead to reduction in other costs. The actual energy is greater than the theoretical because all developed processes involve large thermodynamic losses. Reduction of these losses will reduce costs.

25. In distillation, the transport of water across the liquid-vapor interface involves little thermodynamic loss. Serious losses, however, result from the use of large temperature differences between heating steam and boiling water. Ultrafiltration, by contrast, involves large losses in the osmotic membrane; the necessary work-energy can be supplied with good efficiency by a pump. What seems to be required is a process having the high "membrane" efficiency of distillation, but with the efficient energy supply possible in ultrafiltration.

26. There is no fundamental reason why the theoretical energy should not be approached in a practical process. What is needed is basic research to provide a better understanding of the fundamental science underlying the various methods by which salt and water can be separated. This understanding will provide the basis for invention and process development.

Research Needed in Desalination

27. Desalination research and development in the United States has been devoted largely to engineering modifications and refinements of older processes. The Office of Saline Water is now embarking, however, on an expanded program of basic research.

28. A conference organized by the U. S. National Academy of Sciences was held in the summer of 1961 to consider those research areas of promise. The reports of that meeting are now available[7,8]. The conference concluded that a broader base of fundamental science is necessary in order that present processes may be improved and better ones conceived.

29. The National Academy conference strongly emphasized the need for more fundamental research on water, electrolytes, transport of both water and ions in the liquid phase, across phase boundaries, and in membrane materials. Too little is known about salt solutions. Thermodynamic properties of sea water at elevated temperatures are needed. The mechanism of scale formation and the growth of deposits on heating surfaces is not now understood. What is the effect of magnetic and electrical fields, and of sound vibrations, on transport and on scale deposition and growth? What are the barriers to transport of either water or salts across phase boundaries? A quantitative evaluation of thermodynamic losses in existing processes should focus research attention on the most important problems.

30. Basic research on nucleation and growth of crystals is needed to support

the development of new and better freezing processes, both water ice and hydrates. Large crystals are needed if they are to be easily washed free of brine--what determines their growth rates, and how can growth be effected with the least chemical potential? Hydrates which form at low pressures and at temperatures well above 0°C. have only begun to be studied.

31. Both organic and inorganic membranes need study as possible materials for the ultrafiltration process. Are hydrated ions literally filtered, or does water transport require the dissolving of water in the membrane substance? What should be the ratio of amorphous to crystalline substance in the polymeric materials? Should ion-repelling charged groups be incorporated in osmotic membranes? Though ultrafiltration is a very old idea, research on the fundamental physics of osmosis has been neglected.

32. Biology has much to offer which is relevant to desalination, and to the broad water problem. What is the structure of the natural membranes employed by plants and animals to control salt absorption? Perhaps synthetic membranes containing polypeptide chains might simulate nature and be better for osmosis. Nature employs ion pumps, which, if understood, might suggest new approaches to the manufacture of membranes for electrodialysis. Natural photosynthetic desalination organisms need study to see what lessons they offer. Can algae or sea plants be used in a cyclic-staged process, employing the properties of such substances of absorbing water preferentially?

33. This brief review suggests the nature of the needed program of basic research, as contemplated by the National Academy Conference.[8] Much money and effort have been directed, with considerable success, to the development of existing desalination processes. But the law of diminishing returns is beginning to apply, and desalination costs are too high for most water uses. The hope for inexpensive water in the future rests on the understanding of basic phenomena, which may be expected to come from a wide-ranging and imaginative program of fundamental scientific research.

EVAPORATION REDUCTION

34. Evaporation from water surfaces is a major cause of water loss. Meyers[9] estimates that the gross annual fresh-water evaporation from exposed water surfaces in the 17 U.S. western states is approximately $28.9 \cdot 10^9$ cu.m. The average annual evaporation from Lake Mead is about $0.984 \cdot 10^9$ cu.m, which is a volume greater than the storage capacity of most reservoirs in the United States. Obviously, any techniques for reducing evaporation will result in increased water supply.

35. Evaporation losses can be minimized by exposing as little water surface as possible. Therefore, if sites permit, it is advantageous to construct deep reservoirs. When several sites are available, consideration should be given to the location with the lowest rate of evaporation in making the final selection. However, the most promising method of reservoir evaporation reduction is through use of protective films. This procedure will be described in more detail later.

36. Another method of reducing water losses is the use of underground storage instead of surface reservoir storage. Some success has been achieved in the artificial recharge of ground water reservoirs and research into improved techniques is continuing. However, the extent of artificial recharge seems to be limited in some areas by the slow rate that water will percolate through the ground.

37. Evapotranspiration is not considered a loss when the moisture is being

utilized in the growth of beneficial crops and plants. However, the water used by non-beneficial plants, such as phreatophytes, should be classified as a consumptive waste. Phreatophyte eradication is one method of reducing the evapotranspiration losses, but to be effective, requires repeated and expensive treatment. Other solutions are the diversion of the water to other uses and the substitution of beneficial for non-beneficial plants. Maddock[10] stated, "It is simpler to keep water away from saltcedars [a phreatophyte] than to keep saltcedars away from the water."

38. As indicated previously, a very promising method of reducing the evaporation from lakes and reservoirs is by application of a protective film.[11] Crow and Daniel listed the characteristics of a material needed to suppress evaporation effectively without harmful effects:

"a. It must create film which has great resistance to the movement of water vapor but must not appreciably restrict the free movement of oxygen, carbon dioxide, and other gases through the water surface.

"b. It must be capable of resisting the action of wind and dust, and must be self-sealing after separation by excessive wind or boats.

"c. It must be capable of maintaining a compressed monolayer by dispensing molecules at a rate sufficient to overcome losses by wind and biological attrition.

"d. It must be nontoxic to humans, animals, and marine life."

39. Tests indicate that the most effective compounds for obtaining a film to meet these requirements are the long molecular chain alcohols, hexadecanol and octodecanol. Research on the use of hexadecanol as an evaporation suppressant was initiated by E. K. Rideal in England in 1925[12]. Research in the United States was started by Langmuir and Schaefer in 1943[13]. A comprehensive bibliography now exists on the use of monomolecular layers for reducing evaporation losses[14,15,16] but special mention should be made of the papers by Mansfield[17] and LaMer[18].

40. Hexadecanol and octodecanol are bland, almost odorless, waxy solids produced from animal, vegetable, and marine oils. They are hydrophobic-hydrophilic in character. The OH group at one end of the molecule is attracted by water and the hydrocarbon at the other end is repelled by water, causing the molecules to stand nearly vertical. Provided a sufficient supply of hexadecanol is available, the molecules will continue to be dispensed from the reserve supply until they become closely packed, forming a compressed monolayer. A monolayer is an effective barrier to water vapor only when it is compressed.

41. Laboratory tests of hexadecanol and octodecanol indicate potential reductions of evaporation of 50 percent or possibly more. However, field-scale tests in the United States using hexadecanol indicate water loss reductions of about 10 to 30 percent. Specifically, some field results were 9 percent reduction at Lake Hefner, Oklahoma[19], 14 percent at Sahuaro Lake, Arizona (1960)[20], 8 percent at Lake Cachuma, California (1961)[21], and 43 percent (1957) and 22 percent (1958) for two lakes in Central Illinois[22]. The main difficulties encountered in the field use of monomolecular layers are: (1) inefficient application of films (2) maintenance of film (3) biological effects on film. Detailed descriptions of the various techniques developed for application of the film are found in the literature.

42. A major problem during large-scale field tests is the maintenance of the protective film. At Lake Hefner, it was found to be impractical to maintain a film when wind speeds exceeded about 10 m. per sec. The wind also causes loss of film-forming material by piling it on the shore. When the shore lines had steep walls, the protective film tended to re-form. Bacteria will consume the film-forming chemicals at a rate of 0.23 to 0.34 kg per hectare per day.[23]

43. A major consideration in the application of a chemical to a reservoir is its effects on quality of water and on fish and other wildlife. The tests at Kids

Lake in Oklahoma City[24] resulted in the general conclusion "insofar as criteria of water quality, including taste, odor, color, toxicity, and other chemical qualities are concerned, nothing has been determined from this study to preclude further consideration of Lake Hefner for large-scale evaporation reduction investigations with hexadecanol." A report of subsequent tests at Lake Hafner [19], a water supply reservoir for Oklahoma City, concluded that:

"1. Public health aspects. There were no apparent toxic effects, no undesirable effects on the treatment processes of the lake water, and no interference with normal recreational uses. A large increase in bacterial content of the lake water did occur, but this was not deemed significant.

"2. Effects on wildlife. Although long term ill effects upon wildlife may be forthcoming, no acute toxicity to wildlife was observed during the investigation."

44. In summary, the application and maintenance of monomolecular films on large reservoirs present a number of problems that must be solved before the technique is economically feasible. Thus this technique for evaporation reduction cannot be expected to contribute to increased water supplies in less-developed countries in the immediate future.

45. An interesting recent development has been research to reduce transpiration from crop plants through application of fatty alcohols to soils. Roberts[25] reports that preliminary experiments in Illinois with mixtures of hexadecanol and octadecanol resulted in reduced transpiration with no apparent effect on growth of the plants. However, transpiration control is a controversial subject and some research experiments have ended with negative results. Several research studies on transpiration reduction are currently in progress.

ARTIFICIAL PRECIPITATION

46. The subject of rainmaking through the treatment of clouds with nucleating agents such as dry ice, silver iodide (ice crystal nuclei), hygroscopic particles (condensation nuclei), water sprays, and more recently, artifical electrification of clouds, has been widely investigated over the last decade and a half.[26] Experiments are continuing, and only a brief general consensus of the more carefully designed and scientifically conducted experiments completed to date will be given here, together with citations of sources of more detailed information.[27,28,29,30,31,32,33]

47. Although cloud modification and precipitation initiation had occasionally been achieved under special conditions, the claims of significant amounts of rainfall reaching the ground, prevalent in the late 1940's and early 1950's, have not been validated. There is emerging evidence, mainly from specially instrumented cloud physics aircraft, use of radar in conjunction with other experimental controls, and cloud census studies, that the microphysical events in natural clouds, which seeding techniques seek to influence, may often proceed at high efficiency for reasons which are not yet completely understood. That is, in a given cloud with rain-making potential, natural rain and snow formation is already underway by the time appreciable condensed moisture is present. Those clouds that might be susceptible to treatment are generally found to be either extremely infrequent,[34] or to contain only trivial amount of condensed moisture, when judged in terms of that required for significant quantities of rain to survive evaporation losses between the cloud base and ground. The probability of a given cloud precipitating and the amount of rainfall released appear to be dictated or at least dominated by larger scale atmospheric processes, especially the structure, vigor, duration, and extent of ascending moist air currents as they influence the lateral and vertical dimensions of cloud systems.

48. The more optimistic theoretical estimates of effects from cloud seeding are now of the order of 10 percent of the amount of increase in rainfall over that expected naturally. Similar decreases cannot be completely ruled out at this time because of both physical and statistical uncertainties. The statistical difficulties of validating such small artificial effects (small relative to the extremely large space and time variation characterizing natural rainfall) is indicated by a recent four-year series of U. S. experiments over southeastern Arizona [35] Using measured rainfall amounts from a high-density raingage network, it was estimated that well over a half century might be required to detect a 20 percent effect.

49. In summary, it appears that water supplies from the atmosphere are determined mainly by geography, by climatological factors and by the large-scale features of atmospheric circulations, and that attempts at artificial modification have not produced consistent economically significant results.

LARGE-SCALE WEATHER AND CLIMATE MODIFICATION

50. In contrast to cloud seeding, which aims at localized effects, there has been increasing speculation of late into the possibilities of large-scale (individual storms or continental, hemispheric or global scale) modification of weather and climate.

51. Large portions of entire storms, such as hurricanes, have been seeded and although interesting effects were observed on the radar screens, no conclusions could be drawn as to the effect on the intensity or movement of the storm itself.[36] Since hurricanes are prodigious producers of fresh water (Hurricane CARLA was estimated to have caused more than 40 billion metric tons of rain to fall over the Mississippi Valley in one day in September 1961--enough to have supplied the fresh water needs of the United States for more than 2 months!), it is tempting to speculate how to "tame" these storms to be benefactors rather than scourges of humanity. But much more must be learned about their origin and mechanics if Man is to probe for weak spots to exert control of one of these monstrous storms, whose energy is so tremendous that in one day, its winds could, if properly harnessed, provide the electrical energy needs of the United States for six months.

52. The present climatic regimes, including distribution of precipitation, are by-products of the large-scale circulations set into motion by unequal heating of the earth's surface by the sun--inequalities introduced by differences in latitude and the thermal contrasts between large land masses and oceans, with the rotation of the earth playing an important role. A rational explanation of the present climatic regimes, starting from basic principles and the particular land-sea configuration and other properties of our planet, has not yet been formulated.

53. One of the most interesting climatic contrasts is that existing in Africa, from the equator northward to latitude 20° where the annual rainfall decreases from 1500 mm. to practically zero. The humid southwest monsoon brings in warm, moist air south of 20° N Lat. in summer, while the hot, dry northeast trade winds cover the area to the north of this northern tropical front. T. Bergeron[37] has proposed sea water evaporation factories, powered by atomic energy, to enrich the southwest monsoon with additional humidity which would then be carried with the winds into the interior of Africa, increasing the frequency and amount of rain and at the same time moving the northern tropical front farther north because of the cooler air.[c] The economics or dynamics of this interesting suggestion were not elaborated upon but it is a good example of the sort of proposal that must await the availability of suitable mathematical models to determine its meteorological feasibility.

54. Within the past half-decade, there has been notable progress in developing mathematical models of large-scale atmospheric circulations, which, despite greatly simplified conditions, bear amazing similarities to the real atmosphere[38] [39,40]. On one of these models, basic physical parameters have been varied to observe the effect on the circulation pattern. An interesting result occurred when the poleward gradient in solar radiation was doubled: the number of planetary waves in the circumpolar westerlies thereupon decreased from 5 to 4. This would mean the elimination of an entire family of storms covering a strip of the earth's surface 8000 km. by 3000 km. Likewise, the halving of the poleward radiation gradient would mean the creation of a new storm system with its attendant precipitation pattern.

55. Despite these theoretical possibilities, no one has suggested practical means of changing the poleward gradient, which Nature does so easily as the sun changes its declination from winter to summer and back to winter. Nevertheless with more and more realistic mathematical models of the atmosphere, it may well be that vulnerable spots in the atmospheric cycle, amenable to Man's relatively puny energy and logistic resources, may reveal themselves. When this day comes two cautions must be observed: first, we must be quite sure that the models are accurate enough to predict that the desired beneficial results and not harmful unexpected changes will come about;[41] and second, that whatever is done, is done by international agreement, since such large changes in atmospheric circulations will affect many, if not all, countries of the world.

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c. Dr. Bergeron has also written a manuscript, apparently unpublished, entitled, "Possible Future Man-Made Climatic Changes", which was presented before the Department of Meteorology, Imperial College of Science and Technology, London, in early April 1961.

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United States of America

RURAL ELECTRIFICATION AND RURAL DEVELOPMENT

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RURAL ELECTRIFICATION AND RURAL DEVELOPMENT *

by
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INTRODUCTION

1. Rural electrification in less developed countries is widely viewed by development policy-makers, planners and administrators as essential to rural development. The validity of this view obviously depends upon what is included in the term "rural development" -is it the development of the small village, the cluster of villages, or the market town? Is it the development of a large area such as the block in India, or an entire region like the Cauca River Valley in Colombia, encompassing parallel programs of agricultural modernization and industrial decentralization? Does rural development include social improvements resulting from the provision of such amenities as illumination, radios and refrigeration? The critical question is: "electrification for what specific purposes?"

2. This paper examines the relationship between rural electrification and rural development by considering the role and socio-economic significance of small power generating units in the development of village communities, and alternative approaches to relating rural electrification projects to viable rural development opportunities. It is clear that the productive use of electricity in rural areas depends upon effective load-building programs integrated with rural electrification programs.

SMALL SCALE POWER UNITS FOR VILLAGE DEVELOPMENT

Electrical Energy Generation

3. Field investigations were carried out recently in rural areas of India, Colombia, Chile and Peru to assess the need for and the impact of electrification on rural development. At the outset it was hypothesized that a small scale engine generator capable of utilizing a variety of indigenous fuels would be an effective and economical means of supplying from ten to fifteen kilowatts of electric power to rural villages. This hypothesis was not borne out in either India or Latin America from the generation or productive utilization standpoints.

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4. In the limited number of instances where it was judged that the local generation of electrical energy could make a productive contribution at the village level (population 2000-3000), the field studies showed that a 50 Kw unit would be the minimum size required. In addition, it would be advisable at the outset to install excess capacity for future load growth. Further, some reserve or standby capacity should be provided to assure a dependable supply. These requirements are well above those originally estimated, and have substantial implications for the alternative fuels that can be considered.

5. It was found that, in practically every case, supplies of local fuels such as wood, rice hulls, dung, straw, leaves, etc., were insufficient to meet the daily requirements of an engine-generator of adequate size on a dependable basis. Figure I shows the estimated daily fuel requirements of a 15 Kw generator powered by a closed-cycle compound steam engine. Some of these fuels are seasonal in supply, e.g., rice hulls and straw, and are too bulky to stockpile. Some have other uses besides fuel -agricultural mulch, fertilizers, building materials, or animal feed. Some are concentrated geographically, for example coal in India and Colombia, where the cost of transporting coal into the villages is an effective deterrent to its widespread use. Wood is available in certain areas, as in the Indian State of Orissa or in southern Chile, but in general wood is either not available in the quantity required, or is too expensive.

6. The bio-gas generator which has been developed in India for animal dung offers a limited potential as an energy supply, and has the added advantage of producing a fertilizer residue. Family size units of 100 cubic foot daily capacity have been built and tested by the Indian Agricultural Research Institute. Gas production of this unit is sufficient for lighting (4-5 cubic feet of gas per hour for a gas lamp) and cooking (10 cubic feet of gas per hour per burner). At its current stage of development, however, the bio-gas unit is too expensive for the average villager.

7. Widespread distribution systems for diesel and gasoline fuels exist in both Latin America and India. Under these circumstances, reliable internal combustion engines would appear to be the most appropriate equipment for local energy generation. However, diesel power is usually too expensive both in terms of the ability to pay and existing rural electric rate structures. This is particularly true in India, where the price of high speed diesel fuel in rural areas ranges from 50 to 60 cents per U.S. gallon, reflecting the high tax designed to discourage consumption of imported petroleum fuels. It is less true in Colombia and Peru where domestically produced diesel fuel is considerably cheaper, ranging from 10 to 16 cents per U.S. gallon. The cost of diesel-generated power in India based on a 50 Kw unit operating at a 30 percent load factor using high speed diesel fuel at 42 cents per U.S. gallon approximates ten cents per kilowatt-hour. In Colombia the cost would be about six cents per kilowatt hour, with fuel at ten cents per U.S. gallon.

Figure I
Daily Fuel Requirements of a 15 Kw Generator Operating at a 30 Percent Load Factor

Plant	Fuel	HHV (btu/lb)	SFC (lbs/kwhr)	Plant Eff. (%)	Fuel Rate (lbs/day)
Diesel Electric	Diesel Oil	19,750	.75	23.1	80
Gasoline-Electric	Gasoline	20,750	1.11	14.8	120
Closed cycle, compound steam engine electric	Diesel Oil	19,750	1.15	15.0	125
	Bunker C Oil	18,000	1.27	15.0	140
	Coal	11,800	1.93	15.0	210
	Wood	8,500	2.68	15.0	290
	Agricultural Waste	7,500	3.04	15.0	330

HHV-Higher Heating Value; SFC-Specific Fuel Consumption.

8. The upland areas of Chile, Peru and Colombia in the Andes have many glacier-fed streams with a year-round hydroelectric potential of 50 to 500 Kw. Because of their steep gradients (150 to 300 feet per mile) these streams are a potential economical source of locally generated electricity. This resource has been exploited to only a limited extent for rural electrification and many excellent opportunities exist.

9. Wind-generated electricity offers few practical application opportunities in India or Latin America. At Alta Plano in upland Peru, there are sustained daytime winds. The north coast of Colombia also has low velocity (10-15 mph) sustained winds throughout the year. However, these regions also have readily-available gasoline and diesel fuels at prices so low that the generation of any useful level of electricity by wind power would be non-competitive. The most effective use of wind power, where available, would appear to be for pumping rather than for the generation of electrical power.

10. Solar power also appears impractical for near-future rural electrification. Substantial research and development work remains to be done to increase conversion efficiencies and to reduce equipment costs in order to compete with presently-available power generating equipment.

Utilization of Electrical Energy

11. Generally speaking, the on-site investigations of representative rural communities in India and Latin America revealed only limited opportunity for the productive application of electric energy supplied by small scale generating units.

12. Where irrigation is required, direct diesel pumping is, of course, more economical than electric pump sets supplied with electric energy from small scale generating units. Further, given the Indian land tenure pattern of three to four acres in many cases, it is difficult to justify either a diesel or an electric pump. The Indian government is making attempts to consolidate holdings, but in many parts of the country the size of the holdings is so small that even consolidated holdings will require common sharing of pumped water, an arrangement which has so far been extremely difficult to arrange to the satisfaction of the parties concerned. The social problem is the critical factor here.

13. There also appears to be very little potential for the productive use of electricity by small industry at the village level because the traditional industries -weaving, tanning, oil expelling, shoemaking, etc.- cannot begin to compete with the larger and more efficient units in towns and cities. Currently these village industries are economically marginal or sub-marginal, the daily income per Indian artisan ranging between Rs. 50 to Rs. 1.25, or ten to twenty five U.S. cents. Under those special circumstances where it is appropriate to perform certain processing operations at the village level, such as grain grinding or oil expelling in a village that lacks access to a market town, it would appear to be more economical to utilize the shaft power of an internal combustion engine directly rather than to convert shaft power to electric energy to power a small electric motor. For illumination it is usually less costly to utilize kerosene or gasoline-mantle lanterns than to use this same fuel to power a small scale engine-generator supplying electricity to an electric light bulb in the absence of other loads. Productive uses must be developed to achieve a minimum load factor to make electrification practical and economical.

14. Given the present limited opportunity for the productive application of electric energy, which works against the possibility of achieving an appreciable load factor, and given the favorable economics of direct shaft power as against electric energy for satisfying the principal existing requirements for power, it appears doubtful that the introduction of small-scale generating units can be justified at the village level, with the possible exception of small hydro units. This is not to say, of course, that power may not be a worthwhile social and political investment for purposes of improving rural amenities and avoiding dissidence. It is important to be clear with respect to the costs of providing such services, however, and in the absence of significant productive applications of electric energy in agriculture and small industry, to face up to the possibility that uneconomical highly-subsidized electric services may not prove to be permanent.

RURAL UTILIZATION OF POWER IN COLOMBIA AND INDIA

Electricity Utilization in Rural Colombia

15. Figure II presents data on the percentage of the rural population in Colombia with access to electric power. The data indicate that in 1960 approximately 23 percent of the rural population had no access to power, and that the bulk of the population with access to power were supplied by Class G plants (less than 100 Kw). Energy generated by these plants is used almost exclusively for illumination, and it is estimated that about two thirds of the total electricity generated by Class D-F plants (100 Kw-5000 Kw) is also used for lighting during a few hours of the early evening.

16. A review of load factor data for rural Colombia shows a rough correlation between load factor and the percentage of the rural population served, i.e., the greater the rural population served, the lower the load factor. For example in Giradot, 143 kilometers southwest of Bogota, the percentage of rural population in the area served by the local power company is only 8 percent, and the load factor is 40 percent. In Sahagun in Cordoba Dept., the rural population served is 85 percent, and the load factor 20 percent. The load factors of companies providing power from hydro facilities however

are much better than those of diesel generating companies; this is undoubtedly associated with the lower hydro rates, which are about one third of those charged by diesel-based companies. In any case there is a basic need to develop higher load factors.

Figure II
Rural Population with Access to Electric Power in 1960
(Unit: thousand persons)

	1960	Percent
Total Rural Population	8436	100
Est. Population without power	1973	23
Population served by B, C, D, E, F, Class plants	3014	36
Est. Population served by G Class plants (less than 100 Kw)	2734	33
Population with grid power	715	8

NOTE: Rural population is defined as persons residing in communities of less than 1600 inhabitants. The total 1960 rural and urban population of Colombia was 14,987.

17. Although electricity from small scale diesel and hydro generators had been available to a number of the rural communities surveyed for 30-40 years, there was a singular lack of application of power for purposes other than evening illumination. This indicates that the mere availability of limited power is insufficient to bring about productive applications. It also suggests that there has been little comprehension of alternative productive uses for power.

Electricity Utilization in Rural India

18. The degree of rural electrification differs substantially in various Indian states. Four states that have made much progress have electrified the following percentages of their towns and villages: Kerala (36%); Madras (32%); Andhra Pradesh (8%) and the Punjab (10%). Various factors have tended to facilitate rural electrification in these areas. In Kerala there is a relatively low proportion of smaller villages -only 12 percent of the villages have a population of less than 500, compared to the all-India average of two thirds. In Madras and Andhra Pradesh also, the typical village tends to be somewhat larger in size. Significant irrigation pumping loads in these areas supplement lighting loads, and, in addition the Madras, Kerala and Punjab power systems include a substantial proportion of low cost hydroelectric power.

19. It must be pointed out that even though these states are first electrifying the optimum villages from the standpoint of load building and use factors, rural electrification programs are still very heavily subsidized. In Madras,

for example, the State Electricity Board has estimated that the total annual subsidy to rural users in 1958, when only 4000 villages were electrified, was 1 1/2 crores of rupees, or 3 million U.S. dollars. This subsidy is estimated to total almost half the cost of supplying rural electricity, and is high in relation to the planned annual investment under the Third Five Year Plan of 6 crores of rupees to extend electricity to the remaining 8000 villages in Madras. Despite the subsidies and rates as low as 1.5 to 2.0 cents per kwhr, use factors are extremely low.

ELECTRIFICATION AND VIABLE RURAL DEVELOPMENT PROGRAMS

Indian Village Industry Programs

20. India's village industry development programs date back to the teachings of Ghandi and his followers, who created the All India Spinners Association and the All India Village Industries Association to revive and encourage traditional rural industries including the "charka" (hand spinning) and weaving industries. There were important social aspects of these efforts, and village self-sufficiency was a prime objective. A great deal of effort has gone into programs aimed at implementing these ideas. For example, in 1956, as part of a national small industry program that was having considerable impact in urban areas, 26 pilot projects were sanctioned in villages with the special aim of accelerating rural industrialization. Both new and traditional village industries were established. Of the 26 pilot projects, only 15 were really started, and of these only 9 were considered successful. The most successful in the final analysis were those involving traditional industries: namely, spinning and weaving. Even here the "successes were heavily subsidized." The evaluation of this effort made in 1959 stated: "The experience of these projects shows that where there is no electricity, and other facilities for the growth of small industries are lacking or are inadequate, and where the area is generally backward, a program of assistance to traditional and village industries can still be undertaken..."[a] It is generally recognized that the results of these efforts have not been encouraging. Industry has gravitated to those centers where it can operate most effectively, namely where raw materials, labor, power, transportation, capital, and markets are all available. During 1951-57, 47.2 percent of the new manufacturing enterprises in India were located in Class 1 cities of over 100,000, 19.3 percent in Class II and III cities (20,000-100,000 population), and 33.1 percent in towns of less than 20,000 population.[b]

The Village vs. the Market Town as Nodal Growth Center

21. In Colombia the typical "vereda" is a collection of huts, inhabited by 200 to 500 persons engaged in non-mechanized subsistance farming. The traditional grouping of people in a vereda is based on ready access to the small plots of land farmed and on social and security considerations, rather than on present-day economic factors. For marketing and the purchase of necessities,

[a] Report of the Study Team on Community Development Industrial Pilot Projects, Ministry of CommunityDevelopment and Cooperation, Government of India December 1959, p. 50

[b] Bredo, William: Industrial Development and Urban Growth with Particular Reference to Industrial Location, Paper 9, Seminar on Urbanization in India, University of California, Berkeley, California (1960.

the inhabitants of veredas travel to the nearby "pueblo" or market town, which usually constitutes the administrative and economic center of the larger "municipio" or county. Retail merchants and wholesale buyers of coffee, yucca, sugarcane and livestock typically operate in the market town. The principal church, schools and the circuit judge for the municipio are also located in the pueblo. The municipio areas surrounding these market towns vary widely in size and in the proportion of rural and urban inhabitants, although there is a rough correlation between the total population of a municipio and the number of pueblo inhabitants.

22. It would appear that the existing concentration of economic activities and population in the market towns offers the most promising economic base for rural industry, mid-way between major modern urban areas and small veredas. The pueblo also appears to offer promise of the greatest economic return for rural development programs associated with the productive utilization of electric energy. The generally ready access by villagers to the market center further suggests that economic and social improvements in the pueblos would have an impact on the rural inhabitants of the municipio in terms of higher employment, income and amenities. Possible types of small industry suitable for market towns in Colombia that can help build productive electric power loads include: agricultural product processing, construction materials, leather goods, woodworking, pottery and apparel. It cannot be assumed that any given industry would prove successful in any locality, of course, inasmuch as the availability of markets, raw materials, management, and capital will vary. The data in Figure III relate average power requirements to other characteristics of industries in various size categories ranging from 1 to 9 employees up to 25-50 employees.

Figure III
Electric Power Requirements for Small Scale Industries in Colombia - 1959

Category of Industrial Establishments by Number of Employees	Number of Industrial Establishments per Category in Colombia	Total Installed Horsepower per Category	Average Horsepower per Industrial Establishment	Average Kw Required per Industrial Establishment
1-9 empl.	6550	40,400	6.2	5
10-24 empl.	2326	47,400	20.4	15
25-49 empl.	835	54,700	65.5	50

Source:
Government of Colombia, Departmento Administrativo Nacional de Estadistica, via Banco Popular, Bogota (1962).

23. In India it is difficult to conceive of the small village as an initiator of new industry, although the traditional industries (khadi, coir, handlooms, etc.) have evolved over time within the village. Modern small industries imply a degree of specialization and urban training not available within the village. This training must be imported by either bringing entrepreneurs and skilled workers to the village or by selecting promising villages and training them. The Karve Committee, which helped pave the way for the small industry program in India, had this to say about the pattern of industrial decentralization.[c]

> "The pattern of industrial activity that should gradually emerge is that a group of villages having its natural industrial and urban centre. These small urban centres will be similarly related to bigger ones. Thus a pyramid of industry broad-based on a progressive rural economy will be built up. In such an organization small centres can experience a cooperative interest in the bigger ones, and these latter would develop a genuinely supporting instead of an exploitational relationship towards the smaller towns and the countryside."

24. This brief discussion highlights the fact that the issues of urban versus rural development, or centralized versus decentralized growth, and regional balance in development, are clouded by many complexities. In the meantime, economists, sociologists, and planners will have to do some "educated guessing." This kind of educated guessing was undertaken by a large number of high level officials and economists who attended a seminar on rural industrialization sponsored by the Ford Foundation in March 1960.[d] The main conclusion of this meeting seemed to be that industrial decentralization would at best mean decentralization from the very large urban centers toward the smaller towns and that rural industrialization could not be conceived of as a village goal, but as an area objective. Within given areas of rural India, nodal growth centers would provide a need and opportunity for clusters of small industries. It is around these clusters, probably located in market towns, that a foundation for rural industry might be established. Similar conclusions appear appropriate for the Latin American situation.

The Systems Development Approach

25. The preceding discussion suggests that there is a need for an approach to rural development that would consider the inter-relationship between the provision and productive utilization of electricity from the viewpoint of the systems analyst. The systems analyst would be concerned with an electrical energy supply system consisting of generation, transmission and distribution sub-systems, and an energy utilization system consisting of the agricultural production, small industry and consumption sectors of the rural economy.

[c] Report of Village and Small Scale Industry Committee, Planning Commission, Government of India, New Delhi (October 1955) p. 22

[d] Morse, Richard, Rural Industrialization in Economic Development, Seminar Report, the Ford Foundation, New Delhi, (April 16, 1960).

The type of generating system and the cost of delivered energy are obviously influenced by the characteristics of the load to be supplied and the utilization system. The "scale" problem is critical in identifying the various types of small industries and processes which are viable for rural areas. Electrification can only be planned in relation to the total rural development program. In anticipating and appraising the impact of energy on a newly electrified area, one must consider both the economic system and the social system. In fact, social factors may well override technical and economic considerations.

26. It is concluded that the market town offers the most promising site for rural electrification projects integrated with viable rural development programs. An effective electric load-building program must be provided to develop productive uses of electricity to achieve an economical load factor; the mere provision of electricity is insufficient. Small-scale (10-15 Kw) generators utilizing local fuels, wind or solar power do not appear to have significant practical application potential. The minimum size generator to be considered for a town of 2000-3000 population is 50.Kw, with additional capacity for growth and stand-by very desirable.

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